ELEMENTARY LESSONS

IN THE SCIENCE OF

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BY

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EXAMINER IN THE PRINCIPLES OF AGRICULTURE UNDER THE GOVERNMENT DEPARTMENT OF SCIENCE

London

MACMILLAN AND CO.

1881

PREFACE.

THIS elementary work has been prepared to meet the requirements of two distinct classes of students. For those who have some knowledge of agricultural practice it will probably act as a familiar introduction to the instruction given in various Manuals of agricultural science. On the other hand, it is hoped that the student who has little or no knowledge of farm practice will find it a convenient sequel to such works. The scope of this elementary book has been limited to a familiar outline of the more important conditions which influence the growth of farm crops; hence it does not extend to the utilisation of these crops by the aid of animal life.

LONDON, *November* 1881.

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CHAPTER I.

THERE is a very great difference of opinion as to what is meant by **Agricultural Science.** It is a term very frequently used to express very different ideas, according to the knowledge and judgment of the person using it; but it is manifestly desirable that there should be a clear recognition of its true meaning. Agricultural Science may be fairly described as "**Scientific truths taught by the Practice of Agriculture.**" It is a definition which will probably lead some to remark, "I thought that Agricultural Science was intended to teach me how to farm, but the order is here reversed, for this makes the Practice of the Farm teach me the Science of Agriculture." Such a comment would be perfectly just, and the title which has been chosen for this book is intended to prevent—as far as may be pos-

sible—any misapprehension as to the general character of Agricultural Science. As soon as we accept this definition of Agricultural Science, we are thereby guided into a safe course for obtaining sound and reliable information on the subject. The laws of Agricultural Science will be most accurately learnt when they are deduced from the practice of farming, and from a careful observation of the conditions which control the production of our crops. When this truth is cordially acknowledged, we see men of science learning from farmers **the science of their practice,** and in doing so they communicate to the cultivators of the soil much useful information, which will lead to improvements in **the application of science to farm practice.** The exchanges of thought benefit both, and as a natural consequence both groups have some new light thrown upon the views previously held, and in each case a thirst for a fuller and more perfect knowledge of the matter will be established.

This result is most perfectly attained when you have the two characters blended in one and the same individual, such as when a farmer has been a student of science, or when a man well educated in science has been engaged in the cultivation of the soil. It is this **combined knowledge of science and of practice** which perfects the judgment, and renders the opinions formed more complete and more accurate. The terms, Scientific Agriculture, Agricultural Science, and Agricultural Chemistry, are very often used as if they had exactly the same meaning. Other

persons fail to see any distinction between Agricultural Science, and the study of chemistry, botany, geology, and physiology; but these difficulties really arise from an imperfect knowledge of the matters spoken of. If, however, the definition already given of Agricultural Science be accepted, there will then be less danger of confusing terms which have such distinct and different meanings. The sciences of chemistry, botany, geology, and physiology, etc., rightly used, are each and all of them of immense value and importance to the farmer. They are, in fact, a series of detached assistant agencies, which require to be brought into concerted action; and the only means by which this can be accomplished for the advantage of the farmer is by the aid of Agricultural Science. This condition of things is not peculiar to agriculture; it attaches to every case in which science is made use of for improving any of our manufacturing industries. All hold one common relationship, but they vary considerably in the extent to which such co-operation extends; and there is no reason whatever why the business of farming should be separated from the series.

The study of pure science is valuable, amongst other things, in enabling a man to inform himself as to the character and composition of the materials he has to deal with. It matters little what the material may be which he has to work upon—it may be either an animal or vegetable product, or a mineral—if he knows its general nature and specialties of character, then he can deal with it with greater success.

The manufacturer studies that branch, or those branches, of science, which have reference to the material he intends dealing with; and he does so in order that he may the more successfully learn the practical details of his business. The study of pure science is as a lamp which aids him to see the why and the wherefore of the operations taking place around him, but he has still to gather the practical knowledge or experience of the business or manufacture, in order that he may work in the light so given. For the interests of farming we want this practical work to proceed under a clearer and brighter light. The several branches of science are ready to contribute their help. Chemistry has done, and will still do, much to throw light upon this work; but it comes, as it were, with its own special tint. Other branches of science are capable of doing similar good service, but when any one is used alone it throws a tinted light. It is when they all contribute to the work that we get the clear and perfect light we need. We have an illustration which happily explains these conditions. White light consists of coloured lights, which are called simple or primitive lights, and these can be separated, giving the varied colours of the rainbow; but when these are blended again we lose these distinctive tints, and reproduce a clear, bright, and colourless light. So also, if we bring a well-balanced and tolerably complete knowledge of science to bear upon agricultural practice, we lose the tints given by different sections of science, and we get a brighter and purer light to aid us in our labours.

Happily for the progress of Agricultural Science, we have a large number of farmers in this country who have received a good training in science, and they are from day to day gathering-in fresh truths from their experience in agriculture, learning valuable lessons from their successes and from their failures, steadily accumulating evidence from Nature's own mouth, and thereby enabling some more complete and definite character to be given to Agricultural Science. Thus, whilst we suggest that a study of pure science prepares the farmer for observing results with greater accuracy, and for tracing those results to their proper causes, we should be guilty of a great oversight if we did not recognise the fact, that the rich stores of knowledge which we find in the minds of experienced farmers, contain many a precious grain of truth, although it may not have been winnowed as clean as if they had had the opportunity of acquiring some knowledge of the sciences. It is a duty to point out the advantages of a study of science as preparing any one for understanding more fully the materials he has to deal with, but it is also incumbent upon us to remember that many have not had this preparation, and yet have struggled on against the stream, gathering-in their contributions to the science of agriculture. These may want more or less winnowing, but those who look upon Agricultural Science as it has been herein defined,—as "Scientific truths taught by the Practice of Agriculture,"—will see that **the experience of practical farmers is the great storehouse of Agricultural Science,** and

that, instead of such science being in any way opposed to practice, it is its very essence, its life, the spirit by which it is animated.

CHAPTER II.

The cultivation of the soil is now regarded by all intelligent men as a manufacturing business of the highest importance to the welfare of this country. It is generally carried out in that rough and ready manner which distinguishes the practice of those who adopt a certain course of procedure, because it will probably lead to successful results. The experience of the farmer is a very valuable guide in the attainment of such results. It should be distinctly recognised as absolutely essential for those who would succeed in the cultivation of the soil, and a possession of this knowledge should be accepted as a necessity of the case. There must be no doubt whatever of the immense value of sound practical knowledge of farm management, for it stands in the same relation to the cultivation of the soil as the rudder does to the ship. An absence of either of these, simply indicates a drifting to destruction, rather than the attainment of success. In both cases the issue depends upon a series of uncontrolled influences, and the probabilities in both instances are in favour of failure and disappointed hopes. A ship with a rudder to guide it may meet with misfortune and

danger; but the value of the rudder is admitted because it so generally prevents loss, and enables the voyage to be terminated with feelings of satisfaction; and a knowledge of practical farming is equally important. Whatever may be our views of the great value of Agricultural Science, we ought always to remember that the only foundation on which it can rest is a sound and practical knowledge of farming operations.

Whilst we thus recognise farm experience as the rudder which controls our course, we may also regard Agricultural Science as the mariner's compass, which indicates to the experienced sailor the nearest and best line for his ship to take. However much we may value the rudder, we know how great are the advantages arising from the supplemental help of the compass. Nor must we forget that neither are of value to any but those who are accustomed to their use. Both, however, become of priceless value when skilfully used.

Thus, in approaching a consideration of Agricultural Science, we must clearly recognise the fact that, rightly and judiciously employed, it may be made **a valuable supplemental help** to those who have a sound and practical knowledge of farm operations. It is as foolish to reject the aid of Agricultural Science as it would be to cast the mariner's compass from the ship; and, on the other hand, any doubt as to the necessity for farm experience is as devoid of reason as an indifference respecting the need of a rudder. Each of these departments

of agricultural knowledge is of immense value—they are not opponents, but joint contributors to success. The prudent man will rightly use both of them, and consistently seek to become more and more fully acquainted with each.

This acquirement of a knowledge of Agricultural Science necessarily claims our attentive thought and steady perseverance, but considerable advance may be made without any undue demands being made on either—especially when the subject is brought under consideration stripped of all needless technicalities. In these Elementary Lessons some of the foundation-stones of the structure will be exposed to view, with a desire to encourage the reader to seek out others which underlie many of the successful practices of the farmer; so that he also may contribute to the fuller knowledge of the subject. It may be readily admitted that our knowledge of the principles of agriculture is very imperfect; and that there is an abundant opportunity for those who are acquainted with the practice of agriculture to discover some of the principles upon which such practice is based. If we accept the experience of the farmer as a rich store of facts from which, by the light of science, we may discover an explanation of the results which have been observed, then, and then only, shall we be adopting a safe and prudent course—especially during the early period of research. We must for a time seek after facts, and investigate the conditions under which these have arisen, rather than look out for such facts as will dovetail in with any precon-

ceived ideas of Agricultural Science. Conscious of the want of more truth to guide us, we shall follow the safest course if for a time we gather out the jewels which have already been brought within our reach by successful practice, and thus labour zealously in the attainment of a more complete knowledge of the subject. We must thoroughly realise the fact that Agricultural Science is really the Science of Agricultural Practice, or, in other words, that it is those lessons of scientific truth which we may learn from the experience of the practical farmer.

But in order that we may be able to learn these lessons, we must first be content to acquaint ourselves with some of the conditions and circumstances which influence the operations of the farm. The soil naturally presents itself to our notice as being worthy of our study. We have spoken of the cultivation of the soil as a manufacturing business, and thus we have **the soil as the raw material**, which has to be converted into those marketable products which are most desirable for a farmer to sell. Other manufacturers use the raw materials which best meet their requirements, but it is from the soil that the farmer has to produce those varying forms of animal and vegetable food which it is to his interest to manufacture. It is therefore clearly desirable that those who are to support themselves by the cultivation of the soil, should have a very complete knowledge of the character of the soil which they have to cultivate. In fact, we may say that it is not only desirable, but actually necessary, if the cultivator

wishes to draw from that soil the largest produce of the greatest value, and at the least cost in cash and material.

The soil is very commonly regarded simply as earthy matter, which is devoid of all interest except as regards the plants which grow upon it. But this is far from being the fact, for as we become more intimately acquainted with our soils we see **evidences of character** which well-nigh constitute them living realities. We find points of character which indicate powers approaching very closely to **tempers, wills, and dispositions,** which the farmer is bound to consider, and which he neglects at his peril. Many a soil is said to have "a will of its own," because if its peculiarities of temper be disregarded much of our labour is expended uselessly. Much of the farmer's success turns upon his familiar acquaintance with those points of character which is commonly known as the temper of the soil, and yet how few stop to inquire as to the causes of these variations. But when these variations in character are traced out, and when a person thereby becomes more familiar with them, it appears almost to invest our soil with new attributes of life. Hence we have become accustomed to speak of soils as being **hungry, or sick, or grateful, and as obstinate, kindly, and tender,** and so on. The plain fact is, the more we know of the soil the more interesting it becomes, until it causes a feeling of surprise that any one can look upon the soil with the indifference which arises from an entire ignorance of its character.

But, besides all this, the soil boasts of **a history** extending over long periods of time, during which it has undergone changes of the greatest importance; in fact, its history gives us a series of incidents of most thrilling interest, and contributes greatly to surround the soil with associations which not only give to the reflective mind subjects worthy of careful consideration, but they indicate to the farmer how he may make that soil a source of greater profit to himself.

CHAPTER III.

As soon as attention is directed to a consideration of the nature and character of the soil, the inquiry naturally arises:—**How were these soils formed, and whence came they?** With **one exception,** our soils have been formed by **the decay of rocks.** It is a matter of common observation that the stones of old buildings do not look as smooth as those which have been more recently built. We sometimes see modern stonework losing its sharp edges by becoming crumbled into dust; but it is much more evident on looking at the stonework of old buildings. Thus we have instances of even the hardest stones undergoing decay on the surface, and becoming in this way changed from hard rock into a soft or a gritty powder. This change on the surface of this stonework is very similar in character to the decay of our rocks, whereby they are made to yield

portions of their surface in that, more or less, finely broken condition which we know as the soil.

The wearing down of the stonework of our buildings fairly represents the mode in which rocks decay, and yield that earthy matter which we use for the purposes of cultivation; but in the one case a very small quantity of soil is produced, and in the other it has been accomplished to an exceedingly large extent. Through long geological periods, which we fail to reduce to figures with any pretension to accuracy, this decay of rocky surface has been steadily and persistently taking place, until at length we have an abundance of this earthy matter distributed throughout the world, and in quantity more than sufficient for the wants of mankind.

A study of geology teaches us that at one period —far, far remote in the world's history—the surface of the earth consisted of rocks which are now known as **the primitive rocks**, or, plainly speaking, the first rocks. We have large masses of these rocks still remaining, so that we can form a very accurate opinion of their nature and character. But a period arrived when portions of these rocks became decayed, as rocks decay now, and then we had earthy matter formed from these rocks, yielding the first soil upon this world's surface. From that time we have had a series of changes upon the earth's surface, which the study of geology partially unfolds to our view; but we have one great fact which it is necessary for the student of Agricultural Science to remember. That **first soil** which has been already referred to has

undergone many changes; it has been **formed into rocks,** and **again turned into soil,** by their decay; changed **again into rock,** and again into soil, and this has been taking place **over and over again,** as our various geological formations were being built up. It is as if some materials of a building had been repeatedly used in the reconstruction of some more recent portion, and that these had been again partially employed in a similar manner. The earliest soil produced from the primitive rocks in like manner has become rock and then soil, and again rock and then soil, very many times. In the periods during which it was existing as soil, it may have been intermingled with the soils produced from other primitive rocks, but of a somewhat different composition, and thus its character may have been changed. The changes which have been taking place have been **a series of reconstructions** of the same original earthy matter, and these have often been modified in character by the influences of animal and vegetable life. Thus the soil of the field has an antiquity of no ordinary character, and it has probably taken part in many of the great changes on the earth's surface. This is beyond doubt a matter of very deep interest, but there is one practical issue which we must not overlook—viz. that as these reconstructions have been taking place in the manner referred to, **we ought to find in the primitive rocks materials similar to** those which we have in **the soils of our fields.** These primitive rocks were the first grand store of solid mineral matter,

the magazine from which all the supplies were drawn, and the various rocks which were found at latter periods of time were little more than reconstructions of the original materials of the primitive rocks. As a matter of fact we do find in the primitive rocks just those mineral matters which now exist in our soils.

These primitive rocks practically consist of **three** tolerably distinct groups, which are known as **Granite, Syenite,** and **Trap,** and their composition is as follows:—

ANALYSES OF PRIMITIVE ROCKS.

	Granite.	Trap.	Syenite.
Silica	72·	43·	59·8
Alumina. . . .	16·	14·	16·8
Ferrous Oxide .	1·5	15·3	7·
Lime	1·5	12·1	4·5
Magnesia . . .	·5	9·1	2·6
Potash	6·	1·3	6·6
Soda	2·5	3·9	1·3
Phosphoric Acid, Sulphur, Manganese	traces.	traces.	traces.
Moisture. . . .	...	1·3	1·4
	100·	100·	100·

If we notice the minerals each of these contains, and trace out their composition as shown by chemical

analyses, we find these primitive rocks differ greatly in the materials each would yield upon decay. Thus the original earthy matter varied very greatly in composition and character; and according to the proportions in which these happened to become mixed, so was the character of the reconstructed rocks modified. So also in the soils which were produced by their decay equally marked variations were to be found. In this way we have immense variations in the character and composition of the soils now existing on the world's surface.

It is desirable, as we proceed, to notice **how the decay** of rocks into earthy matter **is accomplished.** We have seen that ordinary stone buildings bear signs of the same decay which took place in the early period of the world's history on the first rocks on the earth's surface, and which continues to take place at the present time. The agencies are very simple, and easily understood. It is, moreover, exceedingly important that **these agencies** should be familiarly known to the student of Agricultural Science, because they are **valuable friends** to the cultivator of the soil, and it is always desirable to be acquainted with our friendly helpers.

Those who have watched farm work have probably been often struck with the bright polished surface of the mould-board of an iron plough after it has been used on some of our soils, and especially on sandy soils. When the work is completed, and the plough is allowed to stand out in the field, the bright polished surface soon becomes covered with rust. This rust

is caused by something in the air, which attacks the iron. Chemists are able to trace out what it is in the air which does this, and they find that it is a body which is commonly known to us by the name of **oxygen**, which is really at the bottom of the mischief. We also know that this oxygen has a companion in the air which also helps on the work, and it bears the name of **carbonic acid.** These **two gases**—for they are as colourless and transparent as air—are found to help each other very much; and they not only attack metals, such as the bright mould-board we have referred to, but they attack rocks, however hard and tough they may be. If you rub the rusty surface of the mould-board, you can remove a powder, and this shows that the hard metal can be reduced to a soft powder. That powder contains iron, which has been separated from the iron mould-board by these agencies, for even its great strength had failed to resist their attack. If that iron had been beaten or crushed to the greatest possible extent, it could not have been as completely powdered as it was done by these two gases, without any noise, and almost without observation. Thus, although we cannot see these two bodies, we easily learn that they are **very powerful,** and it will cause no surprise when we say that they are equally powerful **in breaking down rocks,** even when those rocks are as hard as granite.

CHAPTER IV.

THE changes of **temperature** and the action of **water** are another pair of agents which work together in helping to convert rocks into soil. As we have already noticed, the two gases in the air helped forward the breaking down of metal and rock into fine powder, and the work was made more effective by their united action. It is just the same with these additional agents; by **working together** these also become **increasingly powerful.** It may be well just to notice how a hard rock is attacked, and how the surface is removed and crushed to powder.

We will take the hardest granite rock, and see how they attack it. It happens that the granite, with all its strength, has **two bodies in it,** which are really prepared to act as **traitors in the camp,** and these bodies are **iron** and **potash.** Both of these substances are commonly known to us all, and we have therefore a certain familiar acquaintance with them. The iron in the granite is soon found to enter into alliance with some of the oxygen and carbonic acid of the atmosphere, just as happened in the case of the iron mould-board of the plough, and after a time we see on the face of the granite a rusty mark. This rusty mark has been caused by the rain-water removing the rust formed on the face of the granite. In fact we have here an exact repeti-

tion of the iron being reduced into a very fine powder, only it is the granite rock which has given it up, instead of the iron mould-board.

After this has been going on for many many years we find **little holes in the granite.** The constant action of these agents is like so many miners driving a number of adits into a rock, and as they send away what they dig, they leave passages open in the rock. So also these **atmospheric miners** make a series of very fine passages in the rock, because they have been removing some of the iron and potash from it, and thereby there is room for water to penetrate and fill these little passages. Whenever a frost comes on, the water in these passages becomes hard, and in doing so it also tries to become bigger. The same sort of thing takes place in the water pipes of our houses when the water becomes frozen. If the pipes are stronger than the force exerted by the freezing water, no damage arises; but if the pipes are not strong enough, then the swelling of the water as it becomes formed into ice bursts the pipes, and when the thaw comes great inconvenience is caused in the house by water coming from the pipes where it is not wanted. It is very similar when the **water soaks into a rock** and then becomes **frozen**—sooner or later it **bursts** off the surface, and reduces it to a broken condition.

The continued attack does not stop even then, for any portions of stone which may thus be thrown off are again worked at just as we have noticed in the case of the rock. These atmospheric influences

are like **a well-trained company of sappers and miners**; they bore out the passages and blow up the parts thus mined, and finally reduce the strongest material to small particles. But they differ in one respect, for their work is constant; **they cease not** from weariness, nor stay for refreshment, but **day and night,** from century to century, they are either driving passages into rocks, or blowing portions of the rock into atoms.

We have spoken of the hard fight which takes place in the granite rock, and the idea may arise that this only happens upon a very small scale; but it will be found that the extent of work thus accomplished, when the world's surface consisted only of the primitive rocks, was something so immeasurably great, that it is beyond our power to understand its extent. The progress of the work is, of course, very much **more rapid upon softer rocks** of more recent date. We see it taking place around us, and we find that rocks which are exposed to the air, as they gradually get covered with soil, so they are more or less protected from the air, and consequently the reduction into soil is held under control. Hence it is that some rocks are so largely covered by soil, and yet beneath that soil we find the hard rock remaining.

In this, as in all the operations of nature, we have some useful purpose to be secured, and when that object has been gained we find no wasteful exercise of power. **The reduction of rocks into soil** has been **necessary,** in order that the surface of the earth may be prepared for its varied duties, and of

these one of the most important is the production of the soil, on which man may exercise his industry and skill, in the **production of animal and vegetable food** and many other necessaries of life. We shall have to notice as we proceed that at the present time the reduction of rock into soil is proceeding far less rapidly than in the past, because the work has been sufficiently advanced to meet the necessities of the case. But we shall also see that the same influences are still constantly waiting to help the farmer, if he is willing to have his soil rendered more fertile and more productive. It is for this reason that it has appeared desirable to speak somewhat freely upon the past work of **these atmospheric agents,** because they may be employed as **friendly helpers** by the industrious and skilful farmer, if he knows how to make use of their powers. For present purposes, however, the explanation given may in some degree throw light upon the inquiry, "How were our soils formed, and whence came they?"

It has already been stated that there is one kind of soil which forms **an exception** to the rest, and its formation is due to two different causes—these are the **peat and bog soils.** Whoever has examined these soils must have observed the fact that they are largely composed of **vegetable matter.** The soils to which we were previously making reference consisted chiefly of mineral matter, and by their appearance to the eye were easily distinguished from those composed of decayed vegetation. In the peaty soils we have the accumulations of vegetable growth

which have been gathered during centuries—and, in some cases, during many centuries—of time. The plants which have made these accumulations have been chiefly those which flourish upon and in water, and are commonly known as aquatic plants. An accumulation of stagnant water appears to have been the first step in the formation of peat. This has sometimes happened from accidental causes, such, for instance, as trees falling across a small stream, and thereby ponding up the water. In the great majority of cases peat has been formed where there has been a basin-shaped surface, in which water has been held. Aquatic weeds soon established themselves, and as they died off their remains sank to the bottom, so that numberless successive generations contributed to this deposit of vegetable matter. At length this vegetable deposit came near the surface; the plant growth then became more luxuriant, yielding larger and more rapid accumulations, until ultimately a turfy growth established itself on the surface of the spongy mass, and by degrees gave it greater firmness and solidity. The height to which the peat could grow was determined by the overflow edge of this basin-shaped surface, for whatever regulated the level of the water indirectly influenced the growth of the peat.

Thus we see there are **two primary groups of soils**, viz.—those which have been formed by the breaking down of **rocks**, and those which are of **vegetable** production. There are, however, many variations observable in those soils which are obtained

from rocks which need some further notice. If, for instance, a cartload of ordinary soil were to be thrown into a stream of water, we should find the water passing away quite muddy; and if it were a strong stream we should find it gradually driving the sand, grit, and stones of that soil further down its course. At length, when the stream is running with less force, we should find the largest stones allowed to rest first; further on the smaller stones, after a time the coarse grit, and then the sand, would be deposited. The muddy water would have probably gone much beyond all these, and when the water became quiet then the finer portions of the soil would be allowed to settle. If we had used a very large quantity of soil in the first instance, we should have formed from it a series of deposits, each differing in its character. If we turned the stream, we might find we had thus formed a **gravel** soil, a **coarse sand** soil, a **fine sand** soil, and a **clay** soil, all produced from the same original soil. Now what had thus been done on a small scale, has occurred naturally on the large scale. The action of water has thus done much to separate the soil produced by the breaking down of rock, so that we get large areas of gravel, sand, and clay soils, all of which have been **separated** and **deposited by water** in a similar manner.

CHAPTER V.

The character of our soils is also greatly influenced by the rocks from which they are produced. Some rocks are composed of minute particles, whilst others are of coarser texture. This is not surprising when we remember that such rocks have been made from second-hand materials, or those which have been previously existing in other rocks, and, as we have seen, may have been so employed over and over again. Rocks, therefore, have their characters modified according to the materials of which they are built up. When our soils are found resting upon the rocks from which they have been formed, the chief difference between the soil and the rock consists in the soil being more or less perfectly broken up. If, for instance, a rock had been formed from a fine sedimentary deposit, when it became again reduced into the form of soil, it would naturally yield a clay soil. Another rock, which had been formed of sand and gravel, would, when broken up, supply a soil of corresponding character. Such is the general result, and hence it is that soils which are found in close connection with the rocks from which they have been produced may differ so widely in their character.

It will be seen that we have many agencies at work in causing the great variations observable in our soils. Some operate in one case, whilst others

determine the character elsewhere. There is no constancy in the conditions which are brought into play, and consequently we have those varieties in the character of soils which, whilst they tax the skill of the farmer, enable him to raise a great variety of produce with greater success than if all our soils were of one uniform character.

This great variation in character renders it necessary that we should be able to distinguish soils, so that we can describe a soil with some accuracy and classify together those which have some similarity of character. For this purpose two very opposite kinds of soil are made use of, to enable us to form our soils into distinct groups. Sand and clay have been so employed because of the contrast in their behaviour. In the sand of the seashore we have the one in perfection, and in the clays used for pottery we have the best examples of the other. The one, when it has been mixed with water, falls to the bottom of the vessel with great rapidity; but the other renders the water muddy, and only settles down slowly after the water has been allowed to rest. There are, however, other marked variations in character; for instance, sand, when it is wet, is hard to the touch: it has little cohesion, it cannot be moulded in the hand into any definite form, it cuts hard and gritty, it allows water to pass through it with rapidity, and it is firm to the foot. Clay, when it is wet, is just the reverse in all these respects: it is soft to the touch, it has great cohesion, it can be easily moulded in the hand into any definite form, it

cuts soft and greasy, it keeps water upon its surface, and it is soft and slippery to the foot.

These two bodies—**sand** and **clay**—have for these reasons been selected as the best means for determining the groups into which our soils may be divided. **This classification of soils** has been arranged according to the proportions in which they contain sand and clay. The course of procedure adopted is so simple that it needs very little skill to carry it into practice. If, for example, it were desired by any person to determine what is the character of the soil of any particular field, he would probably proceed as follows:—In the first place he will have to get a fair sample of the soil, and this he should do by taking a small shovelful from four or six places in the field, mixing them together thoroughly. He will then separate the stones, and having well crushed the soil, pass some of it through a piece of fine wirework (with one-eighth inch mesh), and he will thus obtain a fair specimen of the earth. A weighed quantity (say 200 grains) is then taken; it is soaked in water for some hours (sometimes it is boiled), so as to be sure of having the soil thoroughly softened. It is next mixed with more water and well stirred up, and the muddy water is quickly poured into another glass. It is washed again and again, as long as muddy water is obtained; and in this way the sandy portion of the soil is kept in one vessel, whilst the muddy portion is passed into another. When this muddy water has cleared itself by settlement, it is evident that we have got sand in one vessel and clay in the other, and that

we have, in fact, performed a **mechanical analysis** of that soil. By weighing the two deposits we are able, by the aid of the following table, to see the class of soil to which it belongs:—

	Per cent.
Sands contain from . . .	80 to 100 of sand.
Sandy Loams	60 to 80 ,,
Loams	40 to 60 ,,
Clay Loams	20 to 40 ,,
Clays	0 to 20 ,,

It will be desirable to add to the classification so obtained, whether the soil is mixed with much or little stone; but this is a matter of general observation rather than of weights. Thus persons in different parts of the kingdom have the means of accurately describing soil, and in such a manner that any one can understand exactly what they mean.

Thus far we have only been dealing with what we commonly recognise as the mechanical or physical condition of soils, or, in other words, their conditions of more or less fine division. There is another section of the work which deals with the composition of the soils, and this shows us what bodies are found in the soil, in what proportion, and in what conditions of solubility. These determinations come within the province of **chemical analysis**, and involve operations requiring great skill, even from professional chemists. The chemical analysis of the soil is often looked upon as something which may be easily performed, but as a matter of fact it is one of the most complicated and troublesome analyses which has to be carried out.

The information which may thus be obtained is of immense value to the farmer, provided it can be carried out in a right and proper manner. It is, however, most desirable that he should be able to understand the results of such analyses, so as to put them to a good and proper use. One of the first things we learn by such a chemical examination of the soil is, that only a small portion of our best soils is really ready for supplying plants with food. That which is ready for active service is termed the "**active**" portion of the soil, whilst the remainder is known as the "**dormant**" or sleeping portion. Here, then, we get our first division of the soil—viz., into "active matter" and "dormant matter;" and as we proceed we shall see that this distinction is of the greatest importance to the farmer. The dormant matter must not be considered as valueless; it is sleeping and inactive, but it may be, and generally is, of great value. It forms a sort of reserve in the soil, and is of far greater value as a source of fertility than it generally is supposed to be. If it be rightly treated, it will be to the farmer as the "**reserve forces**" are to that portion of the army which is on active duty. It would be considered unwise to let those engaged on active duty be completely worn out and exhausted before calling up the reserves; but on many and many a farm the reserves are never brought into proper service, and the farms are in consequence completely worn out and exhausted, while possessing stores of fertility which are allowed to remain in the soil in a condition of peaceful sleep.

CHAPTER VI.

ALTHOUGH it has been known for many years past that the fertilising matter of the soil existed in these two distinct conditions, and that only a very small proportion of that matter was in an active and available condition, the chemical analyses of soils have been very generally carried out, as if all the fertilising matter present in the soil were at the service of the growing crop. At one time farmers hoped that the analysis of soils would make the choice of manure a very simple matter. It was argued that if a farmer knew what his crop wanted, and also what he had in the soil, he could easily tell what was the deficiency he had to supply by means of manure. In that expectation he was bitterly disappointed, and it will be of advantage if we clearly understand how this disappointment arose. The plain fact is that analysts too often disregarded the well-known facts already mentioned, and dealt with the soil as if all of it were ready for the use of plants. The natural consequence has been that the analysis of soils has been very generally discontinued. Recently, however, some chemists have consented to carry out the analysis of soils in a different manner, and have taken measures to separate that portion of the soil which is in an active condition from that which is in a dormant state, and thus report upon the composition of each portion.

In this way the farmer can have sound and reliable information, for the analysis of the active portion of the soil shows him what there is in the land which is ready to help his present course of crops. He can at the same time judge as to any deficiency which he ought to supply by means of manures. Under the more usual system of chemical analysis this was all confused, because it was not simply that which was ready for the present course of cropping, but also that which was to maintain the growth of crops during future ages; and the whole was included in the analysis. If a farmer is to be informed by analysis what he has in the soil **available for his crops,** there must be a clear line of distinction drawn between the active and dormant portions of the soil, and he can then gain information which will be valuable for his guidance.

Without at present going into details, it may be convenient to state that plants require a variety of different substances for their full and perfect growth. Not one of these bodies is of any immediate use as plant-food unless it is present in the soil in such a form that it can be dissolved in water, aided by carbonic acid or some organic acid. This solution of plant-food is assisted by the functions of vegetable life, especially as manifested by the minute rootlets in their search for food. Thus water aided by these weak acids is the vehicle by which plant-food passes from the soil into the circulation of plants. Solid matter, which will not dissolve in such water, may be useful mechanically in giving support to the plant,

and in assisting the passage of air and water into the soil, but it is of no service to the crop as a supply of food. The plant will drink and breathe in supplies of nourishment, but it cannot take in solid food; and hence it is that we distinguish that portion of the soil which will dissolve in rain water (or a very weak acid solution) as **plant-food.** This also is the active portion of the soil, which we have already distinguished from the insoluble or dormant matter.

It is a matter of great importance to the cultivator of the soil to inform himself as to the possibility of **making this dormant matter take the active form,** and become ready for aiding him in the growth of his crops. This is quite possible, and under thoroughly good cultivation it takes place to a large extent; but it will probably be useful if we notice how this change is accomplished. The **friendly helpers** in this work we have already referred to, and are those **atmospheric agencies** which were so effective in breaking down our rocks into soil. As on the large scale they maintained a constant conflict with rocks and stones, so here also they carry on the same reducing process, and break up the small fragments of the soil into a still more minute condition.

Having thus increased the amount of surface, we find the rain water—carrying its supply of oxygen and carbonic acid—perseveringly bringing plant-food into solution, and passing it over into safe custody in the soil. In this way large quantities of insoluble matter are brought into an active state, and in our

best soils we find it well and carefully preserved, until the growing crops demand the supply. It will therefore be evident that just in proportion as we allow these atmospheric agencies to act and re-act upon the soil, so we shall the better enable them to change some of the dormant matter of the soil, into a condition available for plant-growth.

It is well worthy of comment in passing that as these atmospheric agencies bring that which was practically useless into a form available as plant-food, they accomplish a work which is **equivalent to the purchase of so much manure.** Hence if, by an examination of the dormant matter of the soil, we find that it contains valuable fertilising matters which are required for the crops, it is clearly more advantageous to allow these natural agencies to produce the supplies, rather than to send away our hard-earned gold to purchase them. It is therefore very desirable for the farmer to **give these friendly helpers every opportunity** for working in his interest.

Let us now notice in what way, and by what means, the farmer can facilitate this work. A thoroughly good cultivation of the soil aids it. If you compare two fields having similar soils—say, for instance, clay soils—we often find these fields presenting a very different appearance in the spring of the year, according to the tillage they may have received. In the one case we will suppose the field has been ploughed deeply in the autumn, and laid up as rough as possible, so as to expose it thoroughly

to the action of the air. In the other case the ploughing has been postponed until the spring. In the former instance we shall find that our friends—the atmospheric agents—have been at work on the land, promoting the decomposition of any sour and acrid matter present in the soil, changing it into good and wholesome plant-food, rendering some of the dormant matter into an active form, and making the soil loose and free for the growth of seed. All this has been done by the action of the oxygen and carbonic acid in the air, assisted by water and frost. In the second case no effort was made to let these agencies effect the same changes, but as the earth lay in its solid bed, and probably with water standing upon it, it was really becoming less fit for plant-growth. So that whilst in the one instance, **proper cultivation in the autumn** was thus preparing the soil for a healthy and luxuriant growth of crops; in the other case, the land was ploughed up in spring sour and tough, requiring very much more tillage than the other, and yet it was not brought into such a productive condition. In the one case we have an increase in the crop at a smaller cost for tillage, and in the other instance we have the help of our atmospheric friends rejected, and the result is not only undesirable, but very expensive. It is well that we should **value these friendly helpers,** and that we should do all we can to accept whatever assistance they can give us.

CHAPTER VII.

THE exposure of the soil to the action of the atmosphere is recognised as a means whereby we may bring the dormant matters of the soil into such a condition that they can be made use of by the growing plant. To all intents and purposes we are enriching the soil, because we change its constituents from a useless into a useful condition. This change takes place with greater force in the winter months, because we then have the powerful assistance of frost to mellow down and pulverise the soil. The work, however, is continued throughout the year by the other agents, and although they have not the help of the frost, yet very much is done without it. In fact, the action of the winter's frost generally leaves the others plenty of work to do before the time of its return.

Another means adopted by the cultivator of the soil to permit of the atmospheric influence being exerted on the soil, is the proper **drainage of the land.** It is commonly supposed that land is drained simply to **remove the water** which is making it wet, but much more than this is accomplished when land is properly drained. No doubt the first change we see is the passage of the water; but we must remember that the water could not run away unless the air followed, and took its place. If some stones were placed in a bucket, and then covered over with

water, it is very clear that the water prevents the air having free access to the stones. If, however, a hole were to be made in the bottom of the bucket, then the water would run away, and the air would get at the stones again. But it may be said—"I see no proof of the statement that the air follows the water. I simply see that the water runs away." Suppose, then, we have some smaller stones, placed in a wide-necked, stoppered bottle. When a hole has been opened into the lower portion of the bottle, the water runs away so long as the stopper is out of the bottle, but the stream stops as soon as we replace the stopper in the bottle. The stream ceases to flow because the stopper prevents the air following, but the water runs again as soon as we let the air rush into the bottle. Thus, the formation of drains in the soil allows the water to run away, because it can draw air into the soil. Hence it has been said, "We drain land as much for the purpose of **getting air into the soil,** as for **getting water out** of it."

The drainage of land is therefore a means of **exposing** much of its surface **to the action of the oxygen and carbonic acid** of the atmosphere; and **as the air passes through** the soil, so this silent conflict takes place. It is, however, an unceasing conflict; day by day, and night after night, the action is **constantly going on**; and just in proportion as the character and condition of the soil permits the entrance of air, so do these friendly helpers of the farmer continue to work away at the soil, and make it more fertile. Hence, whilst poor

and imperfect tillage give very limited opportunities for the dormant matter of the soil to be aroused from its sleep, and become useful to the growing crop, we see that **thoroughly good cultivation and drainage rapidly improve the productive powers of the soil.**

The same conditions apply to a system of ploughing, known as **subsoiling** the land. Its object is to move the soil which lies below that which is usually ploughed, or, in other words, to stir the subsoil. This is a means whereby the **passage of water** through the soil is rendered **more easy,** but as **the air will follow,** the consequence is that this subsoil becomes acted on by the atmospheric air, and thereby made useful for vegetation. Just as we understand the powerful fertilising influence exerted upon the soil by the admission of the atmospheric air, so shall we all more highly value a more thorough cultivation of the soil and the subsoil. The cultivation of the subsoil has been neglected by many who acknowledge the value of a thorough tillage of the surface soil; but the advantages of subsoil cultivation have never been more manifest than during the last three or four seasons.

The benefits arising from **the passage of the atmospheric air** are not limited to the liberation of more plant food. It **sweetens the soil** by changing some of the sour and unhealthy decaying vegetable matter—or, as we generally term them, the organic acids—into the higher form of carbonic acid, which is one of our friendly helpers, and thus,

whilst removing objectionable matters, we thus convert even these into a valuable servant. So also the yellow **oxide of iron** (ferrous oxide) is known to every farmer as **injurious to vegetation**—some would say it is poisonous—and yet under the action of the oxygen in the atmospheric air, its character is **changed**, so that it also becomes **another useful servant**, ready to help the farmer to grow better crops. Besides this there is yet another servant ready to help him, and that is **the ammonia** in the atmospheric air. Now it happens that this is a fertiliser which is very expensive to purchase—we may say it costs £100 for a ton—and yet it exists in the air, so that a very large supply can be gathered from it by the soil. There even appears to be special provisions made in the soil for catching the ammonia, to which we shall hereafter refer; but for the present it will probably be enough for us to notice how many servants there are **waiting to help the farmer** to make his land more fertile, **if** he will but receive their assistance. These ask no wages; they require no time for rest; but day and night, from one year's end to another, they are ready for work, **if they are allowed to do it.**

Much has been said of late about the successful growth of corn for many years in direct succession, and often has the remark been made that it is a wonder that the land does not get worn out and exhausted. It is true manure is used to help these crops, but the crop requires very much more than is so added to the soil; and it must be admitted

that the land has to supply a considerable quantity of food for these crops, but instead of being exhausted, it is sometimes found to become more fertile. The cause of this is, that in such cases every care is taken to secure the help of these invisible friends and servants of the farmer. By having the land well drained, by having the subsoil properly worked, and then by the aid of deep cultivation before winter, the atmospheric air is allowed to pass through the soil, and those agencies, which we saw were so powerful as to break down our hardest rocks, are made helpers to the farmer, and improve the character of his soil.

But after all that has been said during the present generation upon the powers of the soils to permit of these heavy demands, we have simply perfected the system previously carried out by Jethro Tull, and corrected some of his errors. His system of tillage was a powerful argument for a thorough exposure of the soil to the action of the atmospheric air, so that, whilst the soil was mellowed it was thereby also rendered richer in plant-food. The improvements introduced by Mr. Smith under the Lois-Weedon system in Northamptonshire, made these advantages still more evident. In the most recent advances made by Mr. Prout at Sawbridgeworth, we still recognise the fullest advantage being taken, by improved machinery and otherwise, to render the atmospheric air as effective as possible upon the land. Whatever may be our views as to the advantages of a system for the continuous growth of corn, there cannot possibly be any doubt but that it is to the

farmer's interest to make the best of these **natural sources of fertility,** whatever system of farming he may carry out.

CHAPTER VIII.

It has been pointed out that the action of a proper system of drainage favours the passage of water through the soil, and thence it passes away at some lower level. We have seen that as it passes through the land so it draws the atmospheric air after it, and that the soil is thereby improved, as its fertilising powers are rendered more active. But another most important change is accomplished at the same time, for the temperature of the soil is raised, and its capability for plant-growth proportionately encouraged. It will be readily understood that **the passage of warm air** through the soil must of necessity **raise the temperature of the soil,** by its heat being transferred to the land. This is a tolerably constant source of heat during the greater part of the year, especially at those periods when crops are in an active condition of growth, and its influence upon the progress of the crop is consequently of very great value. This is therefore a means for making a direct addition of heat to the soil.

The warmth of the soil is also influenced by removal of the water, which has the effect of keeping land cold. If the water falling upon land as rain

cannot pass through the soil into the drains, or some other channels, by which it may escape, the soil remains thoroughly **soaked with stagnant water.** The warm rays of the sun falling on the land, and the warm breezes passing over it, do very little good to the soil, and do not warm it as they would drier land. The stagnant water **has to be evaporated** —or made to pass away as a vapour—before either the warmth of the sun or the warm breezes can exert their stimulating influence upon the soil, or the crops growing upon it. The cause of this will be understood if we remember that **a considerable quantity of heat is necessary** to change water into vapour. If a kettle of boiling water be placed on a fire, and it receives much heat from it, we do not find the water get any hotter, for the heat so obtained is used for changing the water into steam. There is no material difference in the necessity for this heat, whether the vapour be thrown off from hot water or from cold land. Hence, in observing the stagnant water in a soil, we may safely consider that in the drying of the land, the warmth which ought to be used in promoting the growth of the crop is wasted in doing work which the drains ought to have done. The consequence is that **wet and undrained land** is found to be **cold and unproductive,** and even when crops are grown upon it they are always kept back so much in their growth that **they are much later** in coming to perfection than those grown upon drier land.

Water is very valuable in the soil, and it has many

important duties to discharge; but for the proper performance of its work **it must be kept in motion** —steadily passing on from point to point, and exerting its influence in passing. **Stagnant water** prevents these duties being discharged, and has been well compared to **a dog in the manger.** We are all familiar with the incidents of this fable, in which the dog is resting upon the feed of corn in the manger, preventing the horse eating it, and thereby becoming better prepared for doing his master good service. It is very similar with the stagnant water. It not only does no good, but it prevents a good use being made of the plant-food which is in the soil. The advantages of draining the soil are now very generally admitted. Experience has shown that not only are **soils rendered more productive** by proper drainage, but the **horse labour** of the farm is greatly **decreased,** and the **quality of the produce** is much **improved.**

We have had during the last four years too many proofs of the influence of wet and cold seasons, for us to need to be reminded that these are conditions which are unfavourable to the growth of good crops. The truth is forced upon us much more severely than we like, but some instances have shown themselves which give proof of the value of a thorough cultivation of the soil, and also of proper attention to the subsoil, as well as the necessity for complete systems for the drainage of the soil. Such seasons as these involve great national losses; but upon lands which are not properly prepared for cultivation, we per-

petuate these difficulties even in good seasons. The prudent cultivator of the soil, who recognises those conditions which are favourable for the successful growth of his crops, will adopt measures to secure all the help he can, especially when he sees that his best and cheapest servants are always ready to assist him, if he will enable them to work for him.

In considering the influence of drainage as a means for the removal of water from the soil, we must not overlook a provision whereby soils are **protected from injury,** by land being **over-drained.** If a very small tube be placed upright in a glass of water, the water will rise inside the tube to a higher level than the water in the glass. The very fine hair-like tubes show this power more perfectly than larger tubes, and hence this power is known as capillary attraction. It is due to the water adhering to the side of the glass, and thus it really creeps up the tube. We have exactly the same sort of thing happening in the soil; but instead of the passages being straight and regular as in the tubes, here we have the passages irregular in shape, and made up of broken particles of soil. In the tubes we find that the smaller the passage may be, the greater is the height to which the water will rise. The same rule holds good in the soil, for here also the small passages render the action more powerful. The size of these passages in the soil is largely dependent upon the fineness of the soil; for if the particles of the soil are large and irregular, it is impossible for them to form small passages for the water. Hence we find that a

fine subdivision of the soil greatly favours the supply of water thus obtained.

The influence of this **capillary attraction** is very important during the period of the plants' growth. However well a soil may be supplied with the food needful for the growth of a crop, it is perfectly clear that the plants can only make use of it when it is carried into their circulation by being dissolved in water. The presence of a supply of water to carry in the food is as necessary as having the food to be carried in. **A supply of water** for this purpose is **an absolute essential for** the **successful growth** of the crop. We may for the moment suppose that we have so thoroughly drained a soil that we have taken all the water out of it. Now it is evident that if a supply of water be not provided, the growth of any crop would be dependent upon the occasional showers. This capillary attraction prevents this difficulty, and thus we have small supplies of water brought within reach of the rootlets of the plant, and this water carries the food into the circulation. It is a most valuable provision of Nature for **maintaining the necessary supply**; and as every portion of that supply is made use of, so we find other water rising to take its place.

In the warm summer months, when the surface soil is parched for want of rain, and when the sun's rays are falling fiercely upon vegetation, large quantities of water are needed for our crops, and it is at such times as these that this underground system brings up to the roots those refreshing supplies, which

enable the growth to proceed with rapidity. It may be asked by some, **Wherein is the advantage of draining the land if the water is carried back by this capillary force?** It may be replied that whilst men wish to have a water supply at command, they would not like to be constantly kept in a cold water-bath in order that they may have the water they need. It is the same with plants; if the soil be saturated with stagnant water, the crop suffers from its presence, and becomes unhealthy; but by the influence of this capillary force portions only of the soil are charged with water, and the plant seeks its supply when it needs it. But the condition of **this water supply differs** greatly from that wetness of the soil which one observes in undrained land. The supply is more limited, and is held so lightly in the soil that it is **more like a diffused mist** in the land than as a stagnant pool.

Soils differ greatly in the extent to which this power is found to operate; the **fineness of the particles,** and the **presence of organic matter** largely control the action. Much of the beneficial influence of subsoil cultivation may be traced to the assistance thus rendered. If the mass of soil be hard and unbroken, it matters little whether its particles are large or small; whilst if they have been broken, and the rain and atmospheric air have acted upon them, then we find this **underground water supply** commences, and **according to the completeness of our work** such will generally be the assistance rendered to the cultivator of the soil by another *willing* servant.

CHAPTER IX.

UP to the present time we have chiefly made reference to the mineral matters in the soil, those yielded by the breaking-up of our various rocks. There is another portion, however, which claims our consideration, and that is commonly known as **the organic matter of the soil.** The quantities existing in soils differ considerably, but it is present in all good soils. If a portion of soil be roasted on an iron plate over a fire, we soon find a smoke produced from it; and if a weighed quantity had been so treated, it would be found to have lost weight by the burning. That loss of weight represents the water dried out of the soil, and also the organic matter **burned off.** It may be well for us to see how this organic matter has been obtained by the soil. If we examine the fresh soil produced by the action of atmospheric agents upon rocks, we shall find very little organic matter in such soil, and in some cases none is present. The consequence is that none except the lower orders of vegetation make growth upon it, but as these die their remains become intermixed with the soil. After this has been carried on for a time, and the soil has become somewhat enriched by their remains, then plants of a higher order take their place, and these add larger quantities of vegetable matter to the soil, so that ultimately it becomes intermixed with much of the organic matter produced upon its surface. The

term **organic matter** is generally applied to those portions of the soil which have at some time or other been **organised,** and have discharged functions of animal or vegetable life. They have formed part of some animal or vegetable; they have therefore taken some organised form, and after becoming intermixed with the soil are known as organic matter.

This increase of organic matter which is thus first added to the land, consists largely of a matter drawn from the air, and the carbonic acid of the atmosphere is the chief contributor to the mass of organic matter accumulated in the soil. As we carry on the ordinary processes of cultivation, so we generally increase the quantity of this organic matter. The crops we grow send roots through the soil, which remain there and decay, when the crop, having served the cultivator's requirements, is removed or otherwise made use of. In many cases the stems and leaves also add their quota to the soil, and upon most well regulated farms the farm-yard manure is added to the land, thus supplying it with large quantities of organic matter. In fact the general **tendency of cultivation** is in the direction of thus **enriching the soil** with organic matter.

Some crops, such as the **clovers, are especially valuable,** because they **add organic matter to the soil**; and the same result is observable after land has been laid down in grass for many years. An ordinary observer, in looking at such soils, can see the **numberless small roots** with which the land is charged; and the black colour often gives evidence

to the experienced eye of earlier supplies of rootlets which have decayed in the land. This organic matter has long been known to improve the fertility of our soils, and in very many cases lands have been allowed to **remain in grass,** in order that this vegetable matter may be accumulated in the soil. In some exceptional cases **crops** have been grown for the express purpose of being **ploughed into the soil.** In practice, therefore, there is strong evidence in favour of the beneficial action of such organic matter in the soil.

Let us now see what are the duties which are discharged in the soil by this organic matter. In the first place, it has a tendency to give a certain **freedom to the soil,** which assists the roots of plants penetrating it for their food. Stiff clays, for example, which, from the extreme fineness of their particles, have a tendency to become firm and compact, are greatly benefited by organic matter being distributed through them. In the case of sands we have another, but equally useful, duty discharged by this organic matter. In these soils there is no difficulty about the roots penetrating the land, but there is a want of firmness which is still more objectionable, and in such cases the increase of organic matter is in the highest degree desirable. In each and every kind of soil (excepting, of course, peaty soils) **the intermixture of organic matter is desirable,** and in each case it has some important duty to fulfil.

It increases the power of any soil for **absorbing**

moisture and gaseous matter from the atmosphere; and in the case of sands and gravels, which have not the advantage of the underground supply of moisture we have already referred to, this organic matter often determines whether they shall be unproductive or not. It also **preserves any moisture** so obtained, or which may be gathered from the rain in passing through the soil, and gives it up to the growing plants. In these soils, in which the capillary action is naturally weak, we find the addition of organic matter **assisting the supply of water** for the crop. Nor must we forget that such organic matter is one of the means whereby **manures and plant-food are held in the soil,** when the previous character of the land would otherwise have allowed it to be washed away and wasted. At any rate, the fertilising matter so removed would have been lost to that crop, and probably to the farm also.

One of the most important functions discharged by organic matter in its decay is the **preparation of some of the mineral matter** of the soil for assisting in the growth of the crop. We have already made ourselves familiar with the dormant matter of the soil, and we have seen how vigorously the oxygen and carbonic acid of the atmosphere keep up a perpetual conflict with it, and are constantly working away to render such dormant matter available for plant-growth. The decomposition of the organic matter of the soil contributes to this contest, by the carbonic acid produced by its decay, so that the organic matter is really a means for spreading through

the soil decomposing bodies which encourage and assist these changes. Hence it is that the presence of organic matter in the soil is always necessary, for if it has not one duty devolving upon it, we may be sure that it has others, which always make it valuable to the land.

Some have argued against the necessity for the use of this organic matter, because it has chiefly been obtained from the atmosphere, and therefore other plants, it was said, could get their supply from the same source. This will not bear the test of practice, if for no other reason than the fact that plants possess this power of drawing upon the atmosphere in very different degrees. Even if the needed supply could be obtained, it is evident that other duties which are performed by the organic matter in the soil would be neglected. We must also remember that all this organic matter in its growth has drawn upon the soil for mineral matter in an active condition. The consequence of this is that as the decay of the organic matter proceeds in the soil, so we have a gradual restoration of this mineral matter, and in a form highly favourable for use by the growing crop. So fully does this restoration take place, that it has become an accepted practice on many soils, which have little power for holding manure, to make use of this means for **keeping a supply of plant-food ready for the requirements of the crop.** By the application of farm-yard manure to the clover crop, we are enabled by encouraging the growth of clover **to preserve much of the manure,** which under ordi-

nary circumstances would have been washed away from these soils. In such a case **the manure** takes a new form, and is **built up in the clover plant.** This produces an abundance of clover root which, as it decays in the soil during the growth of the following crop, yields up a large store of fertilising matter. It has the further advantage of **giving this supply of food gradually,** whereas the farm-yard manure would have given a larger supply at first, but much of it would have been entirely lost to the crop before the plants were approaching maturity, and were more than ever requiring assistance for perfecting the crop.

CHAPTER X.

THERE are various terms in common use respecting soils, to which we may now refer, and this is the more desirable because these terms indicate certain practical opinions as to character, which are derived from experience in their cultivation. **Some soils** are described as being **hungry.** This character has been gained by the fact that they are constantly in want of food. Sands and gravels, which have little or no power of holding manures which may be added to the soil, are of this class. They were generally distinguished by an absence of the double silicates and ferric oxide, as well as a short supply of organic matter. Just as a heap of cannon balls, with the openings filled with small shot, will give a free pass-

age for water, so these soils offer little or no impediment to the passage of the rain, and have little or no power to soak up and retain any fertilising matter which may be in a soluble form. Hence the common mode of improving these soils is to add **clay** in some form or other, and encourage the accumulation of **vegetable matter,** thereby increasing the organic constituents of the soil. In this way such soils are rendered more capable of preserving any fertilising matter added to the land, and of securing it for its proper duty of giving food to the growing crop. Just in proportion as this is done, so the land ceases to have that hungry character attached to it.

Another class of soil are known as **tough** and **obstinate.** These are generally found to contain a large quantity of clay, but in the majority of cases they only reveal these points of character when under bad management. For instance, a piece of clay land **ploughed up in the spring** of the year in preparation for root crops, or for fallow, is likely to become hard, tough, and obstinate as it dries in the sun, and to demand an immense amount of horse labour to reduce it to the condition of a good seed bed. If, on the other hand, such a soil had been **well drained and ploughed up in the autumn,** or early winter, and left well exposed to the action of the atmospheric agents we have so frequently referred to, it would have become reduced to a finely pulverised condition in the spring. This change of condition is infinitely more perfect than any state to which we can reduce it by long-continued horse

labour. If, however, after this has been done, the farmer is too anxious to push forward his work, and by cross-ploughing the land he **buries the fine soil,** and brings up earth which has lain too deep for the winter frost to act upon it, then we find he has **exchanged a soft, powdery soil** for one that is **stiff and obstinate.** Thus, whilst he should take advantage of the powers for breaking up the soil by atmospheric agents, he must **not undo the work again,** by allowing the soil to be brought up in the objectionable condition we have named. Yet some of these soils, when they have become **hard and baked,** attain a condition which the farmer recognises as **tender.** If, under these circumstances, a **gentle shower** of rain falls, and the drags and harrows are sent over it **at the right moment,** they crumble to pieces at once. If, however, a little too much rain falls, then they show how tender they are, by becoming muddy and pasty. Such soils as these try the patience of the farmer very severely; but just in proportion as he has **more organic matter** spread through the soil, so they lose these undesirable points of character, and **show less temper** in their management.

We also have other soils which are **kindly** and **grateful,** yielding good and abundant returns for any manure which is judiciously applied. As a rule these soils are generally loamy soils, having sufficient sand and organic matter in them to enable them to be worked without any great difficulty, and sufficient clay to preserve and rightly use the manure they

receive. These are the most pleasant soils to manage, and they relieve a farmer from many of the anxieties which appertain to other soils. They represent those intermediate forms of soil, to which all good management endeavours to reduce those which have too much sand or too much clay. The strong clay soil, by the introduction of organic matter, becomes mellowed, so that it can be more easily cultivated; whilst the sands, by good management, acquire greater firmness of character. Both, as they are thus improved, assume more of the character of kindly and grateful soils.

Then we have our soils which are on the invalid list, and known as "sick." It is with soils as with individuals; there are a great many causes for their not being in a healthy condition. Hence, although we may see signs of sickness, there is a very great variety of cause, and we must not decide upon that cause without due and proper consideration. Soils generally become sick from either of two causes. It may be the presence of some objectionable body or bodies in the soil, or because something which the plant requires is absent from the land. In some few cases both of these causes act at one and the same time. Drainage, deep autumn cultivation, and a thorough exposure of the soil to the atmosphere during the winter months, these will, with very few exceptions, meet the difficulties of the first class. The washing of rain water through the soil is very effective in removing injurious matter, and this is secured by good

drainage and a thorough cultivation. The purifying influence of our friendly helpers, the atmospheric agents, will very generally complete this portion of the work already so well begun.

The second series of causes—viz. the absence of something wanted by the plant, is a very much wider question. As a matter of fact, our crops require almost as great a variety of materials for their structure as we require for building a house; and if the plant has not all the materials it requires, it shows that there is something wanted by its sickly appearance. It is no use sending to the plant what it has already got in abundance, for this will not supply that which is deficient. If a building is stopped for want of stone, it is no use sending on additional mortar. The workman calls for stone: you send him something he does not want, and the work is stopped. So with the crop: it cannot tell you what it wants, but it shows that it wants something, and upon its proper supply the progress of the plant depends. Hence that Law of Agricultural Science which tells us that it is those portions of the plant-food which are the least abundant in the soil which determine its fertility, and not those which are most plentiful.

It will be at once evident that this sickly condition of the crop involves an entire series of conditions to which we have as yet made no reference. In fact, to deal with these cases properly, we must first acquaint ourselves with the requirements of our various crops, and see how far these are fairly and pro-

perly supplied. We shall then be better able to point out the causes of the sickness, which are so often brought under the notice of observant farmers.

For the present, however, in tracing out some of the details of Agricultural Science bearing upon the character and condition of the soil, it has been shown that the soil is far from being that dull, uninteresting mass of earth it is too commonly considered to be, but that it is full of opportunities for research and investigations of the greatest importance. Nor is it simply of value as a matter of scientific inquiry; it affects the proceedings of the cultivator of the soil more deeply than any one, and to him this knowledge will more than ever become a matter of pounds, shillings, and pence.

CHAPTER XI.

WE shall fail to understand many of the peculiarities of soil unless we have a tolerably clear idea respecting the materials of which it is composed. The soil may be regarded as **a mixture of several different substances,** each having its own peculiarities of character, and **each contributing its own individual influence** to determine the general character of the soil. We may compare it to a crowd of persons, which is made up of individuals, each possessing his own individuality of character, but collectively blending those influences more or less perfectly. We

have in our soils a gathering together of materials obtained from various sources, and often mixed in very irregular proportions; but as similar conditions and circumstances sometimes operated over large districts and at other times over small areas, the same general result may accordingly be observable over a larger or smaller extent of surface. Soils may therefore be regarded as a most irregular mixture of decomposed rocks and organic matter, differing very greatly from each other. The consequence is, that if we would have any definite knowledge of the composition of a soil, we must rely upon the skill of the analytical chemist to separate the several substances of which it is composed, and determine their respective weights. In this way we learn what are the substances present in the soil, and we thereby secure some knowledge of its capabilities. In the following table particulars are given showing the composition of some soils which possessed certain general characters, differing in a very marked degree from each other:—

[TABLE.

ANALYSES OF SOILS.

	Fertile Soil. Mulder.	Barren Sand. Sprengel.	Moorland Soil. Sprengel.	Rich Clay. Anderson.	Good Loam. Playfair.	Calcareous. Voelcker.
Potash . . .	1·03	trace	·06	2·80	·80	...
Soda . . .	1·97	trace	...	1·44	1·50	...
Ammonia . .	·06	...	...	...	...	...
Lime . . .	4·09	trace	·13	·83	1·28	52·33
Magnesia . .	·13	trace	·03	1·02	1·12	·31
Peroxide of Iron .	9·04	2·00	·64	4·87	3·41	2·86
Protoxide of Iron .	·35					
Protoxide of Manganese . . .	·29	trace	...	...	...	
Alumina . .	1·36	·50	·78	14·04	3·58	
Phosphoric Acid .	·47	trace	·11	·24	·38	trace
Sulphuric Acid .	·90	trace	·02	·09	·09	trace
Carbonic Acid .	6·08	...	...	...	·92	44·70
Chlorine . .	1·24	...	·01	·01	trace	...
Soluble Silica .	2·34	...	...	..	...	...
Insoluble Do. (clay)	57·65	...	...	61·20	81·26	·26
Do. Do. (sand)	...	96·	81·50	...		
Organic Matter .	12·	1·50	16·70	8·55	2·43	...
Water or Loss .	1·	...	·02	4·91	3·23	...
	100	100	100	100	100	100·46

It must not be supposed that these analyses represent the composition of all soils having the same general characteristics. They simply show the composition of those soils which were specially examined. But whilst thus guarding the reader's mind from any such misapplication of these details, they serve to **show the great variety of substances** found in our soils; whilst some soils are remarkable for an absence of certain bodies which are present in other

soils. It is by the aid of chemical analysis that the character of these constituents of our soils is determined, as well as the proportions in which they exist. The analyses show the percentage of the several bodies existing in the samples of the soils examined. They represent the entire composition of these soils, independent of any consideration as to their utility for the support of vegetable life. These analyses must be held to their legitimate use, which is simply to indicate the substances present in these soils, and is, therefore, altogether apart from the question of their being in an active or in a dormant condition.

Whilst leaving any general description of these bodies to chemical works which deal fully with these subjects, some few supplementary observations may possibly be useful. It will be noticed that the list of bodies found in soils is greater than those found in the primitive rocks; but we must bear in mind the fact that **in addition to these rocks, the atmosphere** and **the sea** became in course of time contributors to the soil, and in this they were assisted by the operations of **animal and vegetable life.**

Of the substances present in soils **Silica** is one of the most common and most abundant. It is very important that the varying conditions in which it is found should be clearly distinguished. In **quartz, flint, and sand,** we have one form of silica; but in this condition it has little, if any, agricultural value. It undoubtedly acts in a physical capacity, and gives mechanical support to the plant; but as a source of

food it is **practically valueless.** In other soils we find the **Silica in combination,** and the alliance with Alumina represents the largest quantities of Silica found in soils in a combined condition. The **Silicate of Alumina** forms the great bulk of our clays, in fact some of our clays are very nearly pure silicate of alumina, and it is not uncommon for clays to contain 98 or 99 per cent of this compound. In both of these forms we have silica in an insoluble condition, and therefore not directly useful as food for the support of vegetable life. It is worthy of remark in passing, that these very pure clays are sometimes described as "**agricultural clays**;" but this is an incorrect description, for however valuable they may be for other purposes, they are certainly unfit for the processes of cultivation. Such clays may be excellent for pottery purposes, or for making bricks, but they have no agricultural value, and should rather be called **pottery clays** than agricultural clays. It will be hereafter seen that these clays only become valuable for the production of crops when other materials are present which are essentially necessary for plant-growth. It is a very popular idea that silica is the chief requirement of the wheat plant, and therefore the presence of silica in the soil is the great object to be aimed at; but for all practical purposes, unless the silica is present in a form in which it is **available for plant-growth,** its utility is simply of a mechanical character, in giving a resting-place for the plant. Reference will hereafter be made to the **Double Silicates**

of Alumina, and these will be seen to have most important duties devolving upon them, not only for the preservation of valuable alkaline matters, but also for giving the growing plant its supplies of silica in a soluble form.

Phosphoric Acid is, like silica, a weak acid at low temperatures, but when heated it becomes exceedingly powerful. In the soil we have to deal with it under such conditions that it is exceedingly feeble in its action. It rarely constitutes more than ·5 per cent of our richest soils, and many fertile soils contain much smaller supplies. Its value as **a constituent of all good soils** has long been recognised; and as **all our cultivated plants** require a supply, a deficiency of this body is soon detected. It appears as if it were a provision of Nature, **to enable our crops to be of proper feeding value** in the support of animal life; for the plant makes as powerful a claim on the soil for Phosphoric Acid, as the animal does upon the crop for this material which it needs for the formation of bone.

Organic Matter is found in all fertile soils, and has very important duties to perform. It is not that the organic matter necessarily makes the land fertile, for there are many soils which contain it in large quantities, but they are still unproductive. The presence of organic matter is only **one of the conditions of fertility,** and although its influence is very important, it is not of itself capable of making a soil productive. The organic matter may be removed from the soil by burning it, and it passes

away as a smoke intermixed with watery vapour. This burning of the soil is the usual means adopted for separating the organic and inorganic matters of the soil. If the soil had been dried and the quantity of water determined, the process of burning will generally cause a further loss which may be calculated upon as the organic matter of the soil. This consists of **the remains of animal and vegetable growth,** which have been added to the soil.

The composition of these organic matters varies considerably, and they have very important duties to perform. It may be here stated that those organic matters which contain carbon, hydrogen, and oxygen (but no nitrogen), form a series of dark-coloured earthy bodies known as organic acids, and these have been formed into the following groups:—

The Humic Acid group, in which carbon is combined with the elements of water.

The Ulmic Acid group, in which carbon is combined with the elements of water and an excess of hydrogen.

The Geic Acid group, in which carbon is combined with the elements of water and an excess of oxygen.

It will be seen that these chiefly differ in being more or less fully oxydised, but the ultimate condition to which they may attain is a conversion into carbonic acid and the elements of water. The decomposition of those organic bodies which contain **Nitrogen** very generally results in the production of **Ammonia**; but in some cases the nitrogen takes

the form of **Nitric Acid,** the result being of course influenced by the conditions under which the decomposition takes place.

CHAPTER XII.

THE practical value of the soil is also influenced by its **physical properties,** and one of the first of these conditions which arrests our attention is the **variation in weight,** or the **comparative density** of soils.

				lbs.	
Sand	weighs when	dry	about	110	per cubic foot
Loam	„	„		95	„
Clay	„	„		75	„
Peaty Soils	„	„		30 to 50	„

Here we see **the density increasing with the increase of sand,** and we find **the density decreases with** any addition of **organic matter.** As a general rule the greater the density of the soil, the less is the probability of the land being injured by **treading**—as for instance in feeding a crop on the field—by sheep. A distinction must be clearly remembered between this weight of the soil, and the meaning which is commonly attached to the terms **heavy** and **light** soils. Sands for instance are considered light soils, and yet for a given bulk they weigh heavier than all others. Clays are called heavy soils, and yet for a given bulk they weigh light. The fact is the terms heavy and light, so

applied to soils, refer to **the horse-power** required to cultivate them, and do **not** describe **their weight.** The amount of horse-power necessary to plough a clay soil is greater than is required for a sand, and it is consequently said to be heavier ploughing. This arises from the friction being greater by reason of **the adhesion of the soil,** which may generally be traced to the fineness of the particles of which it is composed. Sand is just the reverse; there is a coarseness of texture and a gritty character, which has **little tendency to hold together,** or even **to stick** to any implement. An example of this is seen in comparing a plough which has been turning over a clay soil, with another which has been working in a sand. The one has a mould-board, generally having some soil sticking to it, whilst the other is as bright as polished steel.

The state of **mechanical division** observable in our soils, is well worthy of a careful consideration. Some soils, such as **clays,** are already in such a state of **fine division,** that we cannot expect to reduce the particles of these soils into a more minute condition. The endeavour of the farmer is rather **to separate these particles,** and prevent their forming the dense and compact mass which many of our soils present. Nothing is more effective in this direction than the introduction of **organic matter** into the soil. If, for instance, we compare the close and compact condition of some of our clay soils, with a good clover-ley grown on such land, we find the particles of soil separated, and **held apart mechani-**

cally, by the roots of the clover plant. The same separation is often attempted when chalk and similar applications are used upon the land. We shall have occasion hereafter to notice these agricultural processes more fully, but it is desirable to realise the fact that the fine state of division in which the earthy matter exists in our clay soils is very frequently in itself a source of difficulty.

In like manner the mechanical condition of many of our sands gives an instance of a difficulty just of the opposite character. Here we often find what is really a collection of minute gritty stones, and in too many cases with little soft earthy matter intermixed with them. The difficulty is increased when this sand consists of fragments of quartz, and being tolerably pure silica, so that it necessitates other matters being added to the soil before it will be in a position to yield any food for plants, for the decomposition of such sand could not yield the necessary food.

But between these two extremes we have a great variety of soils, which have an entirely different mechanical condition. In fact we find large stones, small stones, coarse grit, fine grit, earthy matter, existing in them in a regular gradation. Thus there is often a gradual change of form taking place, according to the tillage operations carried out; whereby the materials of the soil are steadily modifying their mechanical condition, and thereby coming more fully under the influence of chemical agencies. The presence of stony

matter in our soils must **not**—as a rule—be regarded simply as **an encumbrance.** It exerts a mechanical influence upon the finer particles of the soil in the manner already stated, favouring the admission of **air** and **moisture** into the soil, increasing its **friability** of character, and in some cases acting as **a shield** from the sun's rays, at a time when moisture in the soil is of great value. Hence the wisdom shown by many farmers in **cracking stones,** and leaving them on the land, **instead of removing them.** There are other considerations which demand attention, especially the relation of these matters to various chemical agencies; but we are here dealing with the mechanical influences which are called into operation.

The fine or coarse state of division in which the particles of the soil exist has another important influence, to which attention has already been directed. Such is the power exerted by the soil in bringing up **a supply of water** into the land to a greater height than the general water level. Most persons have noticed water being placed in the saucer in which a flower-pot may be standing, and they have seen that it has been drawn up into the soil in the pot. The natural tendency of the water was to remain at the low level, and hence in such cases it must be drawn up to a higher level by some other power. This power is largely dependent upon the mechanical division of the soil. It is known that if a fine glass tube be placed in water, we have the water adhering to the side of the tube by a surface attrac-

tion, and it rises above the level of the water in the glass. The smaller the tube the greater the height to which it rises, and this action is especially observable when the tubes are so fine as to be of a hair-like character. For this reason these tubes have been called **capillary tubes,** and the power by which the water is raised is known as **capillary attraction.** This power is possessed by soils very much in proportion to **the fineness of the particles** of which it is composed, for passages are formed between these particles of a larger or smaller size, according to the finer or coarser condition of the soil. The mechanical condition of the soil in this way very materially influences this supply of water to the growing crop, which is especially valuable in excessively hot weather. When the soil contains decaying **vegetable matter,** this also **favours** the capillary powers of the land.

Closely connected with this power is the ability of the soil **to hold water.** It has been shown that

lbs.				lbs.
100 of sand	commenced dropping	when it had	received	25 of water.
100 of Loam	,,	,,	,,	40 ,,
100 of Clay Loam	,,	,,	,,	50 ,,
100 of Clay	,,	,,	,,	70 ,,

Thus the power of holding water **increases with** an increase in **the fineness** of the particles of the soil. It thus corresponds very closely with the capillary powers of the soil, even if it be not due to the same influence.

The power of **absorbing moisture** from the

atmosphere is possessed by soils in somewhat corresponding proportions, thus :—

lbs.			lbs.
1000 of Sand in 12 hours of the night gained			2
1000 of Loam	,,	,,	21
1000 of Clay Loam	,,	,,	25
1000 of Clay	,,	,,	37

So that in this respect also the power of absorbing moisture from the atmosphere steadily **increases with** the increasing **fine condition** of the particles of the soil.

The possession of these powers naturally increases the productive character of land, somewhat in the proportion in which these powers operate, and it is curious to notice that there appears to be some connection between these mechanical conditions and **the rental value** of land. For instance—

lbs.				lbs.
1000 of Bagshot Soil, worth (say 4s. or 5s.) per acre absorbed				3 of water.
1000 of Coarse Sand,	,,	15s.	,,	8 ,,
1000 of Sandy Soil,	,,	28s.	,,	11 ,,
1000 of Soil from Essex,	,,	45s.	,,	13 ,,
1000 of Fertile Soil from Somerset,			,,	16 ,,
1000 of very Fertile Soil from E. Lothian			,,	18 ,,

But whilst we recognise this influence of the mechanical structure of the soil, as **contributing towards its fertility,** it is equally necessary to regard it as **only one of the causes** of fertility. It is probable that many **peaty** soils of **low productive power** possess each and all of these powers in **a higher degree** than any of the soils which were

experimented upon. That these powers are of great practical value, in their influence upon the productive powers of the soil, has been clearly established; but we shall hereafter have occasion to show that a variety of circumstances contribute their respective shares to the work to be accomplished, and render it desirable that each and all of these agencies should be carefully taken into account.

CHAPTER XIII.

It is probable that a proper appreciation of the influence of the mechanical condition of the soil upon its productive powers, is one of the points of management in which a good farmer excels. As a matter of fact, it is equally important to take care that the soil shall be in such a state as will enable plants to search after their food, and to receive it in a healthy condition, as it is to provide that food. It has already been shown that fertilising materials are not of necessity plant-food, because they may be present in an insoluble condition. But even after they have taken a form in which they are ready for the use of the plant, the mechanical condition of the soil often interferes with the efforts of the growing crop to secure its food. We have therefore not only to secure the presence of the materials necessary for plant-growth, and to have those materials in an available form, but we must

also take care that the mechanical condition of the soil is favourable for that food being utilised.

The judgment and patience of the farmer are sometimes severely tested, in catching the land just in that condition which is desirable for securing successful growth. We often hear the remark made, that a farmer must thoroughly understand the natural character of the land he has to cultivate. This goes far beyond any question of its composition. A man may have a most accurate knowledge of the materials present in a soil; he may also be able to state what plant-food the soil contains, but absolutely unable to show that tact and skill which are necessary to regulate the mechanical conditions of that land. There is much more involved in the management of the soil than appears to the superficial observer. It is in consequence of this familiar acquaintance with the temper, disposition, and character of the soil, that the farmer succeeds in his management, even when he is not informed upon the chemical constituents of his soil, nor is acquainted with the mysteries of plant-life. A knowledge of these scientific details will be most valuable if it be rightly used; but if they are relied upon as something which supersedes a knowledge of the practical management of the soil, to which reference has been made, then it becomes a snare and a delusion. On the other hand, if a combination be made of both classes of knowledge, great additional advantages are secured, and a higher and more economical success will probably be gained. The mechanical condition

of the soil has been **too generally undervalued** by some of those who advocate an acquaintance with Agricultural Science, and hence it is the more necessary to draw attention to the immense practical importance of the subject.

Much of a farmer's success depends upon the character of the "**seed-bed**" which he secures for the crop he cultivates. With some soils far more care is necessary than with other soils; in fact we find almost **as much variation** in dealing with different soils, **as with different animals,** or even with different individuals. For want of some better terms we speak of the temper, disposition, and character of soils just as if these points of character were manifested by living animals; but powers of a somewhat corresponding character are manifested by soils, and a familiar acquaintance with the practice of agriculture shows that these powers **must be considered** by the cultivator if he would secure success. The means whereby the desired conditions of the seed-bed may be secured will differ, but the necessary conditions to be provided are tolerably constant.

The germination of the seed necessitates the three well-known conditions of moisture, warmth, and air, but when we have to secure these in the soil the mechanical conditions of the soil have to be considered. For securing germination in its healthiest form, the **regular admission of moisture** into the seed is a matter of the utmost importance. Special provision has been made for carrying this moisture into and throughout the seed, and we find

a series of **irrigating channels** used for this purpose. Thus, water supplied to the surface of the seed does not simply moisten the skin, and thus penetrate more and more deeply into the seed, but under healthy conditions the water is carried **through the seed** by irrigating channels, and a more equal distribution takes place—consequently a more **equal swelling of the seed.** If the seed becomes "**dirty**" the entrances to these irrigating channels are largely closed up, and as a consequence an irregular distribution of moisture, resulting in an irregular germination. Here then we have mechanical conditions impeding germination. When this takes place in the soil we too often see the unfavourable result without being able to trace out the acting cause; but it is not so with the maltster, for in his case the changes are taking place above the surface. He therefore knows the full measure of inconvenience resulting from the use of "dirty barley." To avoid the seed being injured in this way farmers find it desirable to keep their **seed clean,** and they generally regulate the time of sowing so as to secure the land in that mechanical condition which is most desirable for promoting germination.

It is essential for healthy growth that a moderate **supply of moisture** should be **continued,** as a cessation in the supply results in the germination being stopped. This is well known as one of the results secured in the ordinary malting of barley; but when this cessation of growth takes place in the soil, it is a matter of serious moment to the farmer. It

represents loss of seed, and a thinner plant; hence, in the usual practice of the farm, there is **a depth of soil** secured as a covering for the seed, which shall assist in **retaining the moisture** which is in the soil. The depth of this cover of soil differs in our various soils, some farmers sowing more deeply than others, and as a rule this depth generally represents **local requirements.** The depth is also influenced by another requirement of the seed, namely, **the supply of air.** Thus whilst the farmer improves his supply of moisture by deep sowing, he, in a somewhat similar proportion, decreases his supply of air. He has therefore to **make a compromise,** and his local experience indicates with tolerable accuracy the medium line of safety.

The growth of some **aquatic seeds** at first sight appears to be an exception to this rule, for if they make their growth beneath the surface of the water, it may be assumed that they do not require a supply of air. This is not so, for if their growth be attempted in water which has been thoroughly boiled, so as to drive off the air from it, a very marked difference is seen in the progress of germination. It would therefore appear that during germination some of the seeds of aquatic plants have the power of securing their necessary supplies, by **separating air from the water** around them. The floating sweet-water-grass (*Glyceria fluitans*) is a familiar instance amongst agricultural seeds.

CHAPTER XIV.

THE work progressing upon farms in the spring of the year naturally leads us to consider the seed-bed into which the seed is deposited, and the influence which such a seed-bed is likely to exert on the coming harvest. The proper condition of the seed-bed may therefore be regarded as of the greatest importance. Although this is so self-evident that no one would think of disputing the fact, it must still be admitted that we are too much in the habit of neglecting many of the conditions which are calculated to promote the results we desire. We almost unconsciously drift into certain courses of procedure, without taking into consideration the objects in view. Custom and established usage prescribe a certain depth as being necessary: this quantity of earth is consequently turned over, and the natural conclusion is, that we have thereby provided a satisfactory seed-bed. We forget the fact that the roots of the plants we cultivate desire to strike more deeply into the land, and are by no means satisfied with the conventional four or five-inch seed-bed. As soon as the roots have struck well through the surface-soil, their roots endeavour to penetrate into deeper soil, but they often find an impassable barrier, probably in the form of a plough-pan. This has been caused by the sole of the plough taking its accustomed

track, and gradually pressing the soil into a hard and compact bed. These plough-pans, in course of time, become so tough that the plough naturally glides above them, and simply renders them harder by each additional ploughing of the upper soil. In many cases we find that, from long-continued working, these plough-pans become almost as hard as rock, and constitute very formidable barriers against the progress of the roots. Thus the roots become confined within a small portion of the soil, and as their powers of searching for food are greatly limited, so also must the productive energies of the crop be limited also. The cultivator consequently suffers, by reason of a decreased supply of plant-food yielding a smaller crop than he ought to have obtained.

In the preparation of the seed-beds for our crops, our first consideration should be to secure for the roots as large an area of feeding-ground as possible. If, after a farmer had taken a large field, he permitted a barrier to accumulate which prevented half of the surface being used, prudence would suggest the removal of the impediment. If, however, instead of doing so, the farmer, unconscious of the barrier, crowded the half of the land with the stock which would have done well upon the entire field, he would soon find that their growth and condition became unsatisfactory. To remove the barrier would be the common-sense remedy, and then he would profit by their enlarged feeding-ground. The frequent existence of these plough-pans in our soils is an equally unreasonable impediment to plant-growth,

and, consequently, to the more profitable cultivation of the soil. The impediment being "**out of sight**" does not lessen its power for checking the farmer's success, any more than if it were seen. Being out of sight, it is of course frequently "**out of mind**" also, for no one would allow a similar decrease of feeding-ground above the surface. As it is, the roots of the growing crop are to a great extent kept within the four or five inches of upper soil, and they draw upon the food present so severely that manure has to be largely supplied to enable a fair crop to be produced. To carry forward the simile already used, the stock being kept within half the field, would need a supply of food to maintain even a moderate progress. The perpetuation of this loss is only permitted because the barrier is out of sight.

This is an **impediment to agricultural prosperity** for which we need no legal enactments; it is a voluntary encumbrance which will be cast aside as soon as any farmer recognises the fact that it exists. Neither will he be content to adopt the expedient of making good the damage by a supply of manure. There are many and great advantages arising from the use of **manure**; but when its use induces a person to neglect that **thorough cultivation** of the soil which is desirable, then its assistance is sadly misapplied. The important services rendered by artificial supplies of fertility have rather induced farmers to place the **mechanical condition** of the soil in a **secondary** position. This is very undesirable, for all manures should take the position

of **assistants** to good cultivation, and never rank as **substitutes.** They are both parts of a good system; each has its right and proper share of duty to perform, and it is by their combined powers that the most successful results are to be secured. Tillage of the soil may for a time render the use of manure unnecessary, and the employment of manure may help to cover up the necessity for perfect cultivation; but we should rather encourage a co-operation of those agencies by which the most successful results may be obtained. Let each be well and judiciously made use of, and we shall find them valuable helpers in a good cause; but they should **never** stand in the position of **competitors for favour.**

Another and very serious disadvantage arising from the **plough-pans,** to which reference has been made, is the interference it causes with the **passage of air** through the soil. We know the importance of a supply of air for the support of animal-life; and although in the case of plant-life the requirement is less urgent, it is none the less necessary, for the action of the air in the soil is of the greatest importance for promoting its fertility.

Closely associated with this subject the very important duty of ploughing the land before winter claims consideration. Simple as this work may appear to some, there are circumstances associated with this tillage which are too often overlooked. The autumn or early winter ploughing should be very thoroughly done, because it is the most important opportunity we have for **deepening** the staple

of the soil, and for increasing the quantity of the soil on which the farmer has to work during the course of cropping, for which preparation has now to be commenced. An experienced farmer, whose soil may be too shallow to meet his views, and who knows that it rests upon a subsoil of a sour or unhealthy character, seizes this opportunity for bringing up some small portion of that subsoil. By the exposure of this bad soil on the surface many and great changes take place. It is by no means uncommon to see the surface, which by such ploughing is for a time rendered very variable in colour, resuming in the spring its usual appearance. We have seen some of these sour subsoils brought to the surface in this way, and in moderate proportions, which have rendered the field like a variegated carpet; and many a doubt has been expressed as to whether such a field has not been seriously and permanently injured. The exposure to wind, rain, and frost during the winter changes its appearance, and also renders it more capable for supporting vegetable growth.

To the ordinary observer this goes far to remove the fears caused by the variation in colour first observed. Experience has trained the eye of many a farmer, to determine with great accuracy, how far colour is indicative of a fertile or a barren condition of soil. The chemist is able to explain the changes which have thus arisen, and thus we know that not only is there a change in colour and general appearance, but a change in the composition also. We not only find many a soft and sticky clay subsoil thereby

converted into land which looks free from all objection, but reduced into a finely broken condition in every way favourable for the growth of seed. In this way many a farmer is able to **increase the quantity of soil** upon any given space of land, and he thus secures more **raw material** at his command **for manufacture into meat or corn,** without any increase of rent, rates, or taxes. This mode of increasing the soil is greatly favoured by previously moving the sub-soil, so as to allow the drains to draw water and atmospheric air through it. This really commences the exposure to the air and rain, so that when it is brought to the surface much of the change has already been accomplished.

CHAPTER XV.

IT is an old saying that "what is worth doing, is worth doing well," and it is probable that this is as true in its application to the cultivation of the soil as it is in any case which can be selected. Half measures are very generally unsatisfactory, but especially in the case of agricultural operations. The cultivation of the soil by **spade husbandry** has long been known to yield a largely **increased production.** There are, of course, many reasons against the general cultivation of the soil by means of spade labour, but the lessons we learn from its success are very valuable. As a matter of fact, one

great cause of this success is the **thoroughly complete** character of the work which is accomplished, and thereby more effective **cultivation** is attainable. Here, then, we have the model from which we may copy, and this result we should endeavour to attain, by those means which are within the command of the farmer.

The condition of the soil attainable by spade culture differs from that usually arising from ordinary tillage operations in two respects—viz. in the **depth** of the work and in the more perfect **division** of the soil. Both of these have important influences upon the productive powers of the land. The increase of depth gives a **larger** command of **feeding space,** and consequently gives increased opportunities for deriving that nourishment which is essential for growth. The more complete the division of the soil, the more easily will the roots penetrate throughout the land, and thereby the **increased supplies of food** are more easily made use of by the growing crop. The increased produce obtainable by the more perfect tillage of the land admits, therefore, of a clear and distinct explanation, even if we simply observe these two variations in its mechanical condition.

It may be said that the opportunities for spade cultivation are far too limited to be of any great service to persons farming under ordinary circumstances. This may be allowed to pass with the remark, that we may still strive to secure equally good results by such means as are within the farmer's command. If we admit that the two advantages

named—the greater extent of feeding-ground for the crop, and the easier search for plant-food—are desirable, we shall not long delay doing the best we can to secure these, so far as our opportunities permit.

It is scarcely reasonable to expect that with existing appliances we can equal the efficiency of the spade by means of our ordinary farm implements. These, however, carry us far towards this desirable end, provided they are fully and properly used. Steam cultivation is a very valuable agency in this direction, and when made proper use of in the autumn of the year, it certainly goes far towards giving the land that thorough working which the spade accomplishes. The deep furrow which is thus broken up leaves little to be desired, provided some arrangement be made for stirring the sub-soil. The success of spade cultivation is always secured in the greatest perfection when due care has been taken—by means of double trenching or otherwise—to render the sub-soil free and pervious for water and the roots of plants. Of late years the working of the subsoil has been greatly overlooked, and it has rarely received the care and attention it merits. The most gratifying instances of a successful conflict with the difficulties of the last two or three wet seasons have been associated with proper care in the treatment of the sub-soil in addition to the surface soil. The depth and completeness of the work have greatly contributed to the successful growth of crops during these bad seasons, and although these helps alone are not sufficient to compensate for a want of warmth

and the direct action of the sun in perfecting our crops, still the produce has been materially improved by the good condition of the sub-soil.

The lands which have thus been thoroughly and deeply cultivated, we may be well assured, had previously been well under-drained, and thus a free passage for the water has been maintained through the soil. The drainage arrangements, however good they may have been in themselves, have needed a good preparation of the surface soil, and also a free condition of the sub-soil, to enable them to do their work under the wet and trying seasons we have lately had. Where the land has been properly drained, and the cultivation of the soil imperfectly carried out, there has been, in too many cases, a failure in the crops, thus showing very clearly the great importance of a thoroughly effective cultivation of the soil. If the land requires drainage, this must be provided for in the first instance, but it must be supplemented by good tillage operations to enable it to do its work to the greatest advantage; and the more thoroughly the mechanical condition of the soil is prepared for plant-growth by an effective system of cultivation, the better are the prospects of success.

There are many inducements for adopting measures to deepen the soil. Accompanied, as no doubt it would be, by a thoroughly good tillage of the soil, the produce of the land may be as surely increased as by the cultivation of a greater area. The most successful instances of farming, under the late depressed condition of agriculture, are just those cases

in which, by a thoroughly good course of tillage, the produce of two acres has thus been obtained from one acre. In this way the rent, rates, and taxes of one acre become chargeable against the produce, instead of having double the amount of these charges by the less-perfect tillage of the two acres. The evidence of successful practice is strongly in favour of doing what is to be done in a thorough and effective manner. An increased supply of plant-food we see can be obtained by two distinct means, viz. by taking **a greater breadth** of land, or by **more perfectly working** a lesser area. If on the latter there should be an increase of the horse and manual labour employed, the results are rendered more satisfactory because the produce has to bear a smaller amount of charges in other respects. One of the foundation-stones upon which a thorough tillage of the soil must rest is a properly-conducted autumn cultivation. A satisfactory cleaning of land, and the judicious deepening of the soil before winter—these will greatly favour an increased production from our farms, and assist in rendering their management more economical and decidedly more satisfactory.

CHAPTER XVI.

THE mechanical condition of the soil continues to exert its influence throughout the whole period of the plant's life. It is, no doubt, most powerful dur-

ing the time of germination, but we can never disregard its action without serious loss. No sooner has the seed made a certain growth than the roots begin to establish themselves in the soil, so as to be prepared for duty when the supply of food in the seed is becoming exhausted. Here again two opposing conditions are required—namely, a **freedom** for the extension of the roots in the soil, coupled with the **firmness** which is necessary for plant growth. Variations in soils necessitate different courses of procedure, but the successful cultivator endeavours to secure that combination which is most desirable for his land. Those crops which are found to be the best preparation for other crops are often thus employed. For instance, on some soils vetches and rape are found to leave the land in the best condition for the growth of wheat; on others the clover ley gives a firmer bed for the wheat. These preparatory crops are only referred to, so far as regards their mechanical influences, and entirely apart from all question of composition and plant-food.

The **tillage operations** are often modified for the purpose of securing a better mechanical condition. Thus we have some lands which are secured in their best condition for wheat by pressing the land immediately after the furrow slice has been turned by the plough, and by sowing the seed wheat at the same time, on the land so compressed. In this way many **treacherous soils** are caught in their best condition. It would be impossible to detail the numberless small *variations* which have to be made to contend with

difficulties arising from the mechanical condition of the soil, but **a most important lesson** will have been learnt, if this mechanical condition be looked upon as contributing a very important influence towards the general result. It is **a fatal error** to look upon the chemical composition of the soil as **of itself** indicating the productive powers of land. Such knowledge is of a very great value if it be rightly used, but it only represents one portion of the evidence by which the farmer should be guided in his decisions.

In the preparation of land for seed, regard must be had to **the size of the seed**, and the depths beyond which they cease to germinate with safety. As a rule, **the smaller** the seed **the less open** the surface should be. If a case of shot were emptied on a pile of cannon balls it is clear that the shot would run from ball to ball, and pass down to a considerable depth. When proper care is not taken to have the land in suitable condition, the same thing happens in sowing the smaller farm seeds. Hence it will be found that many local practices hereby receive their explanation and complete justification.

Two very **opposite practices** are observed in reference to the seed-bed for swedes or turnips, which demand a notice in passing. On some lands we find the tillage completed two or three weeks before the seed is sown, the lapse of time being desired so **that the moisture may rise** up from beneath. It is a system which is especially designed for **preserving moisture** in the seed-bed, so that when the seed is

sown there shall be an immediate germination. In the other cases we have exactly the opposite policy adopted. Here the land is encouraged to become **thoroughly dry,** and, so far from any attempt to prevent its exposure to the sun and air, every opportunity is sought for the tillage operations to assist in making the land **not only fine, but dry.** The seed, when sown in such a dry seed-bed, remains **without any commencement of germination** until heavy rain has fallen, and then the growth is so rapid that it rushes into rough leaf with great speed. The danger in the former case is that **growth** having been **commenced** by means of the moisture so carefully preserved in the soil, if **rain** should be long **delayed the plant may perish** before the needed supply of water is received. The peculiar character of the weather during recent years has been so exceptional that these cases have rarely arisen, but when we have a return of dry seasons the same difficulties will be revived.

We have in the **French clover** (*Trifolium incarnatum*) very **exceptional** mechanical conditions required. In this case the free and open condition of the soil is a distinct disadvantage, and the most successful cultivation has been that which secured **a hard and firm seed-bed**—rolling the land after the seed has been sown being preferable even to a light harrowing.

A farmer is not always ready to justify his practice and give his reasons for doing what he knows *to be* most desirable for the soil of his farm, but the

intelligent student will endeavour to seek out the germ of truth embodied in the successful practice of the farmer, and, whilst learning a lesson in reference to the management of the land, he will endeavour to determine the cause of success.

CHAPTER XVII.

PLANTS can only make growth when they have a proper supply of the materials they need for building up their various parts. They have no means for maintaining growth, except by making use of the food they receive. We very generally recognise the fact that animals require proper food for promoting their health and increasing their growth, but we do not as generally remember that plants have an equal necessity for suitable food. We supply animals with their food in many cases, and in other instances we see the supplies on which they subsist. The circumstances are not favourable for seeing plants taking in their food. They are fixed in the soil, and their search for food is carried on under circumstances and conditions which are to a very great extent beyond our observation. If we could see the changes going on in the soil we should be very little wiser, for we should only observe minute supplies of water passing into the roots of the plant. If we could watch the leaves perfectly, we might find these breathing in and throwing off gaseous matter, in a

manner somewhat similar to animals, although that gaseous matter (or, familiarly speaking, air) would not be of the same composition in the two cases. The food of plants, however, is received by them under circumstances which are greatly beyond our ordinary observation. Scientific research has unveiled these hidden and invisible proceedings, consequently we have a tolerably complete knowledge of the manner in which **plants receive their food**, and what **materials they use** for building up their several parts.

A person may have a very ingenious apparatus placed in his hands, so carefully enclosed by an external covering that he is quite at a loss to form any opinion as to the internal arrangements or the materials of which it is constructed. When the apparatus is taken to pieces and examined, he may then discover what materials were employed in its construction. By means of **chemical analysis** this has been done with all our cultivated plants, and thus we know what are **the materials** of which they are built up. We find that a great variety of substances have been so used, and we also observe a certain regularity in the substances which are selected for the work to be done. In determining the composition of plants chemists have found it convenient to separate these materials into two distinct groups. The one group consists of those bodies —**organic matters**—which pass off in vapour and smoke when the plant is burnt, and the other group consists of those bodies which remain as the ash.

Thus we have what are known as "**the ashes of plants,**" and these represent the mineral matter which such plants contained. This mineral matter may be regarded as having given strength and rigidity to the plant during life, enabling its soft and fleshy organs the better to discharge their functions. Thus the structure of the plant consisted of two classes of bodies—the soft matter forming the various **organs** of the body, and hence known as **organic** matter, and the mineral substances which gave them strength, which are sometimes also spoken of as **inorganic** matter, or the ash of the plant. Both are as essential for a healthy plant, as the skeleton and its fleshy coverings are necessary for the body of an animal.

The various materials which are found in the perfect plant have necessarily been supplied to that plant in its food; hence we get a very distinct guidance in determining what is necessary as food, if we take note of the materials which have been made use of for the construction of the fully grown plant. The question very naturally arises as to the substances which are so employed, because the plant must have received all of them by means of its food. Those substances which are found in the ash—or the inorganic matters—of plants, may first receive a passing notice, and they consist of—

Silica.	Lime.
Phosphoric Acid.	Potash.
Carbonic Acid.	Soda.
Sulphuric Acid.	Magnesia.
Chlorine.	Iron Oxides.

These are almost always found in the ash of plants, and they certainly tend to show that plant-food is a somewhat complicated mixture. In addition to these we find in plants a large number of organic compounds built up from four other bodies, in a great variety of forms and proportions. These may be generally described as consisting of three gaseous bodies —oxygen, nitrogen, and hydrogen—and one solid substance—carbon.

It may appear undesirable to introduce the names of so many substances, but if plants will only be satisfied with a long "bill of fare," which shows a great variety of necessary supplies, the credit for this large number of materials must be given to the feeders, and not to the reporters who simply describe the banquet. The form in which these substances are received by plants is almost as surprising as the great variety of materials used as food. No solid matter is received by plants, hence their food enters either as an invisible gas (or air), or in a bright and colourless watery solution. It is very important that this should be distinctly remembered, for it has considerable influence upon the practical measures which are adopted for the successful growth of our crops.

Some exceedingly interesting experiments have been carried out for supplying plants with **food, dissolved in water.** The seed having been sprouted or germinated in very clean quartz sand, the young plant is then removed from the sand, washed in clean water, and afterwards placed over some clean water in a bottle, being

gently fixed there by means of a cork with a hole cut in it. For a few days the roots of the young plant are allowed to rest quietly in the water, but when the first green leaf appears then food may be given. It will be evident that in this way there is an unlimited opportunity for supplying more or less of any kind of food, and then observing the influence produced upon the young plant. The most important point has been to supply all the requirements of the juvenile, and to do so in an agreeable form, consistent with its healthy growth. So successfully has this been accomplished that we may fairly anticipate the time when plant-food will be more generally prepared in pure and delicate form, and suited to the weakest digestions.

CHAPTER XVIII.

As some may be desirous of preparing plant-food, and carefully cultivating some specimens, it may be desirable to describe the best course of procedure. A wide-mouth bottle, or even a glass cylinder, capable of holding from one to two quarts of water may be selected for the purpose. It must be fitted with a cork, and a hole made in the centre about half an inch in diameter. It is often found convenient for the removal of a largely developed plant to have an opening cut from the circumference of the cork to the hole in the centre. The plant can thus be easily

placed in the centre of the cork or glided out from it. The next thing to be secured is **darkness within the bottle,** and for this purpose the bottle should be coated with stout paper, and the neck should be covered with a solution of black sealing-wax dissolved in spirit. Thus we secure darkness within the banquet hall, for **plants feed through their roots best in the dark;** and under these conditions there is less chance of any **green fungoid growth** taking place within the bottle.

We have now to see to **the preparation** of the plant-food, and there is an almost endless variety of banquets which may be supplied. The following one has been selected as suitable for the purpose, and it is a form which has been successfully used by Professor Wolff. Finely powdered burnt bone (300 grains) is placed in a glass flask with water (half pint), and to these nitric acid is cautiously added so as to dissolve the bone, the flask being gently heated. After this has been done a solution of carbonate of potash is added to the hot liquor until it becomes slightly turbid. This represents the only troublesome portion of the cooking arrangements, for it now only needs the three following bodies to be added—nitrate of potash (170 grains), crystallised sulphate of magnesia (107 grains), and chloride of potassium (46 grains), with water sufficient to make it up to a quart. We have thus prepared a very large supply of plant-food; for, although in its concentrated condition it only represents a quart, it will really give about ten gallons when properly diluted.

It is therefore by no means necessary to have fresh supplies frequently prepared. When we are going to use this food for plants we take about two tablespoonfuls and add it to a quart of distilled water, and mix in with it one drop of a strong solution of perchloride of iron. This weak and delicate liquid now represents a very valuable plant-food, and in this condition it is ready for use.

The seed having been grown as already described, the young plant is washed, and then suspended in the hole of the cork (by the aid of cotton wool or soft pith, etc. etc.), with its roots reaching down into the water and its leaves in the air. Up to the time of any green leaf being visible clean water only is supplied in the bottle, but on the appearance of the green leaf the cork and plant are removed from the bottle, the water is poured away, and the bottle is refilled with the properly diluted food.

When the growth of the plant is slow there need not be any fresh supply of food for fully fourteen days, but in hot weather, when the growth is active, it is necessary to give fresh supplies every seven days. On these occasions the bottle is emptied, and an entirely fresh supply of the diluted food is given. The experiments which have been carried out, go far to prove that plants take their supplies in a very dilute form, and yet these minute quantities are really necessary. Take, for example, the one drop of iron solution added to a quart of water (or about 1 to 20,000), and yet this homœopathic supply was

absolutely necessary. It has been found (by Wolff) that when this iron was omitted the young plant was yellow and sickly, but it quickly became green, and assumed a luxuriant growth when this minute quantity of iron solution was added.

In the preparation of these watery solutions it is necessary to use distilled water, if any accurate lessons are to be drawn from the experiments, for all natural supplies of water are more or less charged with the materials which plants require as food. Spring waters are often sufficiently charged with the substances they have dissolved in their passage through rocks and soils, so as to be capable of maintaining the growth of plants without any additions being made to them. Rain water also is always more or less impregnated with matters taken from the air as it falls, so that it cannot be considered pure. The general lessons which we may learn from these facts are, that plants take in their mineral food in excessively dilute condition and in a beautifully bright and clear form, but if they do not receive all the materials they require they soon show that they have some want, by presenting a sickly and enfeebled appearance, which ere long results in a cessation of growth, and finally in death.

Some experiments which have been carried out in these systems of water culture, have led to the conclusion that silica is not always necessary, but it is more than probable that all those bodies which are constantly found in plants when so much more

naturally cultivated upon fertile soils, and which are consequently produced there in the highest perfection, that all the substances they contain are desirable for these plants. Experiments, such as those above referred to, have great value, provided we draw from them sound and useful information; but when they give indications which appear to be inconsistent with the known conditions arising from luxuriant growth under natural circumstances, then these indications demand great caution ere they are allowed to set aside the evidences arising from practical work. Without entering into unnecessary detail, it will be a safer course to accept the constant presence of substances found in the largest and best crops of any cultivated plant as a tolerably sure indication that those substances are desirable for perfect growth. It has been proved in the case of many of these substances that they are absolutely necessary, and it is probable that equally convincing proofs may yet be forthcoming for the entire series. As a matter of prudence the farmer must regard a complete supply as being necessary, and make provision accordingly.

The right and proper use of the valuable researches which have been made in the growth of plants by the aid of these solutions of plant-food in water, gives much information which may be made valuable to the cultivator of the soil. The clean and delicate character of the food received by plants—the bright and transparent stream of water which conveys

the food into the plant—indicate some great changes taking place in the soil when, for example, farm-yard manure has been used upon the land. **The most offensive materials** are often used as **manure,** and are rightly so employed; but the plant does not feed upon them until, by **changes carried out in the soil,** they are passed into the circulation in a condition as **bright, clean, and brilliant** as the water which sparkles in the goblets on our own dining-tables.

CHAPTER XIX.

THE ordinary use of various **offensive matters** as manure for the land, and therefore as a means of supplying **plant-food,** has very naturally encouraged the popular idea that the substances upon which our crops feed, correspond in some degree with the offensive character of the original supplies. It is consequently by no means a generally recognised fact, that plants receive their food in a bright and delicate condition. Many an animal kept upon our farms drinks water far more charged with offensive matter than that in which plants receive their food. It may be well, therefore, to trace **the changes which take place** in the soil, and by which the most **offensive** decomposing masses yield to the plant a **pure** supply of food.

It is a matter of common observation and knowledge, that **the soil is a great purifier and de-**

odoriser of offensive matter. This property differs in soils, for some of them act more promptly and more perfectly than others. **The double silicates** are probably **the most powerful** constituents in our soils, for absorbing with avidity any gaseous substances passing off from decomposing animal matter. Cases are known in which the **application of soil to wounds** on the body has very perfectly cleansed such wounds, more especially in hot climates. The soils which have been so employed are those **clays** in which the double silicates are found, and we may fairly anticipate the time when the prepared double silicates will be used for such purposes, instead of the bulky soil in which they may be present. One of the first changes which decaying manure undergoes in the soil is a complete purification, by the absorption of these offensive matters into the soil, whereby new combinations are produced in the soil, free from the objectionable character which distinguished that decaying animal matter before intermixture with the soil. Decay undoubtedly continues within the soil, but the constituents of the soil arrest the products of decomposition as soon as they are set free, and thus no offensive results arise.

Thus we have a purification taking place in the soil, new combinations being formed, and the rankest masses of putrefactive matter are resolved into pure and wholesome plant-food. But the plant is also provided with its own protective arrangements, which are especially valuable when the soil discharges its

duties in an imperfect manner, for, as it has been already noticed, **soils differ in their powers of purification.** The passage of water into the circulation of the growing plant, is accomplished by one of the most beautiful arrangements conceivable. The roots are generally looked upon as the channels by which the supply of water, carrying the plant-food, is brought into the plant. If, however, we would realise the nature of the inlets, we must examine the root by the aid of the microsoope, for then we are able to detect that which the unassisted eye fails to observe. We see that the more advanced **portions of the roots** are covered with an immense number of **beautifully fine hairs,** and it is through these **minute filters** that the plant secures its **purified supplies of food.**

It is by these means that all the mineral matters found in plants are carried in after being dissolved in water. In addition to these mineral matters some of the nitrogen and carbon present in the soil also gain admission with the water; and as the water supplies hydrogen and oxygen, it is clear that plants can thus receive from the soil some portion of the materials whereby the organic structure of the plant may be built up. It is, however, evident that **the plant-food drawn from the soil** represents the **only available source for the mineral matter** required by vegetation, for the simple reason that there is no other source of supply. It is quite different with those materials which are used for the formation of the **organic portions** of the plant: these are

partially supplied by the soil, whilst **another portion** of the demand is made upon **the atmosphere.**

The duties which devolve upon the leaf are very important, whether we regard them in reference to plant-growth, or their influence upon the atmosphere in which they exist. It may be remarked in passing, that by the **respiration** of animals, by **combustion,** and by **decay,** we have **carbonic acid thrown into the atmosphere in exchange for oxygen,** and by such an alteration in its composition the air becomes less suitable for animal life. The action of **vegetation is a natural corrective,** for the plant breathes in carbonic acid, retains the carbon for aiding its growth and development, and pours out in exchange a supply of oxygen. This feeding upon invisible matters in the atmosphere is carried out by **the leaves** of vegetation, and these organs may be looked upon as bringing from the air some of the plant-food existing there, just as by the roots other supplies are drawn from the soil. The **under side** of the leaves of our cultivated plants will be found covered with myriads of minute openings, known as "breathing pores" or stomata, and these are so abundant that a square inch will generally contain at least 1000 of them. The duty which devolves upon these breathing pores is to bring a supply of air within the cells in the leaf; and under the influence of **vegetable life,** aided by **the light** of day, the **carbonic acid is robbed of its carbon,** and pure **oxygen is thrown off into the air.** In the

absence of light this action is temporarily suspended, and slightly reversed.

By means of these breathing pores, not only carbonic acid, but other gaseous substances which are present in the atmosphere, may be introduced into the plant. Hence we find the leaves throwing off large quantities of moisture in addition to the oxygen, and in the exchange supplying the plant largely with materials for growth. Thus we have **two distinct agencies whereby plant-food is received,** each discharging different functions, and each remarkable for their very minute formation,—the millions of little filters through which the water passes from the soil, charged with its dissolved gaseous and mineral matter as food for the plant;—whilst myriads of equally minute organs are aiding the distribution and use of the nourishment, by exhaling moisture from the leaves, and helping to perfect the conditions of vegetable growth. The agency by which plants receive their food is singularly beautiful and complete, and in every way well adapted for making the best use of any nourishment which may be supplied, whilst at the same time exercising a guardian care over its admission to the plant. If such be the characters of these very trusty "gatekeepers," which guard the precincts of the region of vegetable growth, well may we long to know more of the mysterious changes which take place within the plant, where plant-food becomes endowed with the attributes of life, as it becomes more and more perfectly transformed into a living organism.

PART THE SECOND.

CHAPTER XX.

THE fertility of any soil is shown by the successful growth of those crops which are suitable for the climate of the district in which such a soil may be situated. The climate and management of the land being favourable, the growth of our cultivated crops give distinct evidence as to the productive powers of a soil. All three conditions are necessary for luxuriant growth. If the climate and the course of tillage operations are unfavourable, the fertility of the soil is not enough to secure the production of large and remunerative crops. On the other hand, a favourable climate and good husbandry, cannot make a soil fertile which does not contain the necessary plant-food. In speaking, therefore, of the influence of **plant-food** on the productive powers of a soil, it must be regarded as **one essential condition of a threefold alliance. First,** we require the necessary **supply of plant-food,** which may be shown by a knowledge of the chemical composition of the soil. **Secondly,**

we require **good tillage operations,** which shall secure the proper mechanical condition of the soil, which must be rightly made use of by a man possessing farm experience. **Thirdly,** we require **favourable conditions of climate.** These constitute a threefold alliance, and for the successful cultivation of the soil each of them must contribute its share to the desired success. Hence a proper supply of plant-food is absolutely necessary, but this alone will not secure successful results.

Under a judicious course of farm management the plant-food in a soil will receive careful consideration on the part of the farmer; for unless the crop can obtain the materials it requires for a full and luxuriant growth, **the produce must be limited by any deficiency in the supply.** The requirements of the crop must of necessity embody a supply of all the materials which are contained in a luxuriant yield of that crop. In this respect the productions of vegetable life in a great measure correspond with the structures built by the skill of man; the materials existing in the completed work show the smallest quantities needed for the prosecution of the work. These at least are necessary. Hence it is that **the mineral constituents found** in the ashes of a plant, show **the minimum requirements** of this description of food. We have **no such definite guidance** in the demands made by plants for the building up of the **organic** portions of their structure. It is true that by analysis we can estimate with some degree of accuracy the quantities of carbon, hydrogen,

oxygen, and nitrogen they contain, but we cannot guide our proceedings by these data. So far as regards the three first-named substances, these are abundantly supplied from natural sources. The carbonic acid present in the air enables the leaves of plants to draw from the atmosphere abundant supplies of carbon; but there are other duties to be discharged in the vegetable economy which render a supply of carbonic acid necessary in the soil. The supplies of hydrogen and oxygen need little special care, for the water (which is composed of these two gases) entering into the plant becomes largely decomposed, and yields both of these gases. In the case of **nitrogen** the circumstances are altogether different, and **its judicious supply** is a subject which **demands the greatest care,** and will be again referred to. For the moment we may, therefore, consider that we have especially to secure in the plant-food of any crop—first, the mineral matter built up in a good yield of that particular plant; and secondly, the necessary supply of nitrogen. In the following table a statement is given showing what mineral matters moderate crops of wheat, beans, turnips, and clover contain. It may be fairly assumed that still larger crops will make proportionately larger accumulations of these mineral matters, but this admits of ready calculation according to the circumstances of each case.

INORGANIC MATTER IN CROPS.

	Wheat.		Beans.		Turnips.		Cl
	25 Bushls Corn. lbs.	3000 lbs. Straw. lbs.	25 Bushls Corn. lbs.	2800 lbs. Straw. lbs.	20 Tons Bulbs. lbs.	6 Tons Tops. lbs.	2
Potash . .	7·49	18·21	22·63	89·17	125·73	75·95	
Soda. . .	·97	·90	6·68	2·69	22·98	16·23	
Magnesia . .	3·07	4·11	5·03	11·24	12·27	9·27	
Lime . .	·85	9·34	3·63	33·58	37·87	69·81	1
Phosphoric Acid	11·47	8·15	23·67	12·16	31·11	27·87	
Sulphuric Acid .	·08	5·82	·61	1·83	42·26	36·56	
Silica . .	·84	101·82	·72	11·84	11·66	2·58	
Peroxide of Iron	·20	1·32	·35	...	3·71	2·58	
Common Salt .	·03	·33	·90	7·15	28·69	38·15	
Carbonic Acid .	...	...	...	...	21·71	21·0	
	25·	150.	63·	168·	340·	300·	2

The plant-food necessary for these crops, it will be seen from the above, includes **a large number of different bodies**, and the quantities used of each of these substances varies considerably. The question has arisen in the minds of some whether these bodies are all required, or whether any of them can be replaced by others in the group. It may be safely stated that **for securing a luxuriant growth, each and all** of these bodies **are necessary.** Substitution undoubtedly takes place within certain narrow limits, but the action of such deputies is inconsistent with a full maintenance, either of an abundant yield, constitutional strength, or reproductive power. For all practical purposes any **substitution of one kind of plant-food for another,**

should be regarded as involving **an unnecessary risk** of successful results. Some very interesting experiments have been reported, which were carried out by Mr. Thomas Jamieson, for the Aberdeenshire Farmers' Association, and these experiments are well worthy of notice. The course of procedure may be briefly stated as follows:—Some sand, which had been very fully cleared of fertilising matter, was used as a soil for the growth of some turnips. In one case **all the ingredients** necessary for the growth of the plant were added by means of a suitable artificial manure, and **a perfect development** took place. In a second instance the exhausted sand received a supply of the same manure, except that the **phosphoric acid** was in this case entirely **omitted.** The result was that after a short growth, and a struggle for life, **the plant died.** In the third trial all the materials were added except the **lime,** and in this case also the plant failed to make more than a feeble growth, and soon **died.** In the fourth trial the **potash** was **omitted,** but the plant continued to struggle slowly on, and **did not die as quickly as the others.** On an examination of the sand, it was found that the plant had received a small quantity of potash by the decomposition of the sand, and these **insufficient supplies protracted the life** of the plant, but failed to enable a perfect growth to be attained. The lessons taught by these simple but very interesting experiments, tend to show the importance of plant-food being perfect and complete. The

addition of a **very minute** quantity of **iron** to the plant-food has already been mentioned as being capable of materially altering the character of that food. Plants which had previously made only **a sickly growth,** because of the absence of iron, quickly put on **a rich green** and luxuriant appearance, as soon as the needed supply was added. The same influence has been observed in cases where other materials were absent, and hence it is that in practice it is necessary to have **the plant-food capable of meeting the full demands of vegetation,** if the cultivator of the soil would secure a successful result from his operations.

CHAPTER XXI.

ONE of the natural results arising from plants requiring a supply of **all** the materials they need for their growth, is that **that portion of the food** which is **least** abundantly supplied **determines the fertility** of the land. If, for example, phosphoric acid were to be absent, and every other portion of the plant-food should be present, that land must be a barren soil for any and every crop requiring phosphoric acid. It would be immaterial how abundant every other necessary may be; here is a want which has not been provided for, and this deficiency renders that land barren. Hence the truth, which cannot be too frequently enforced upon the attention of farmers,

that the least abundant portion of the plant-food determines the measure of fertility. It is no use supplying that which does not **provide for the deficiency.** There is a want of some essential for growth, and until this is supplied successful cultivation cannot take place. You give a mason stones and mortar to build a wall; at length he calls for more mortar, and you send him more stones; he builds as far as his mortar will permit, and finally he stops his work. The plant, by its sickly appearance and feeble growth, tells, as plainly as it can, that it wants something. In too many cases farmers purchase what is not wanted, and fail to supply what is needed. Little or no good results, and the manure-dealer has the credit of sending a bad manure, whereas the truth is **the farmer has not supplied the deficiency.** He may have used some **good fertilising matter,** but it has not been suitable for his requirements, and hence it has not increased the productive powers of the soil.

The natural supply of plant-food which needs our special care is in the soil; and as we have seen what our various crops require, it will now be desirable to see how these requirements are provided for. Soils differ very greatly in their composition, but we find that all **fertile soils** contain **all the substances** which our cultivated crops require. It is unnecessary to repeat the long list of substances already given as the "bill of fare" required by our cultivated crops; it will be enough for our present purposes to say that there is to be found **in all fertile soils** a sufficient

supply of **each and every material.** A moment's reflection will show that such must be the fact, for if there were a deficiency of any one of the needed supplies, the soil would not be fertile and productive. So it is also with other intermediate qualities of soils. We say that such and such a soil is but **moderately productive**, and this may arise from some portion of the plant-food being present, but **not in a full and sufficient quantity.** There are cases in which other agencies than plant-food exert an influence in determining the result. Of this class, it is here only necessary to mention the presence of **injurious matter, imperfect tillage,** or a **bad climate.** But, limiting our remarks for the moment to the influence of plant-food, it may be stated that a more or less perfect and complete supply of plant-food in a well-cultivated soil, renders that soil more or less fertile, and in a degree proportioned to the completeness and abundance of the supply.

Numerous cases are familiar to us, especially in the United States, of new lands being reclaimed, brought into cultivation for the first time by man's industry; and yet, after a few years of imperfect corn-tillage, that land has ceased to be profitable for the growth of corn. The result has been a gradual retirement to new soils, which are ultimately given up for the same reason. This failure in the growth of paying crops does not arise from **an entire exhaustion** of the plant-food in these soils, but rather from the fact that **a partial exhaustion** has rendered the supply imperfect and the cultivation unpro-

fitable. As and when circumstances render it desirable for the cultivation of such lands to be renewed, the existing deficiencies will be supplied, and the land will be restored to a productive condition. This will be most economically effected by supplying the materials which are especially deficient, rather than by any attempt to replace the entire supply, previously used up by the growth of corn crops. It is the weak links in the chain which will need to be strengthened, rather than that a new chain will have to be made.

One other important ingredient in plant-food remains to be referred to, and that is the nitrogen which plants require. At present we gain less guidance from the analysis of our crops, than from the evidence obtainable from the experiments which have been carried out upon the living plants. By analysis we obtain the clearest possible proof, that all our cultivated plants require a supply of nitrogenous matter in their food; and hence we know that it is as great a necessity for the successful cultivation of our crops, as any one of the constituents of plant-food already noticed. There is, however, a great variety of forms in which nitrogen may be added to the soil; and it is in reference to the action of these several nitrogen compounds that the actual experience of the farmer at present gives the safest guidance for its use. Under a good system of husbandry the soil is enriched in its stores of nitrogenous matter by the absorption of ammonia from the atmosphere, and by the accumulation of vegetable matter in the soil

rich in nitrogenous matter, arising from the successful growth of the clover plant and other crops. For our present purposes it will be sufficient to recognise the necessity of the supply.

Nor must we omit to notice the fact, that although plants can obtain from **the carbonic acid** of the atmosphere very large supplies of carbon,—which has been noticed as an important element in **plant-food**—yet there are other duties to be discharged by carbonic acid which cannot be fully carried out by that which exists in the air. Acting as it does in the soil, as **a solvent** of hard matter which is required by the growing plant, and which can only gain admittance to its circulation after it has been dissolved in water, for these and other reasons **the production of carbonic acid in the soil is exceedingly desirable.** The idea was at one time suggested that, having regard to the supplies of carbonic acid and ammonia in the atmosphere, it was unnecessary to carry to the land such a bulky manure as that produced in our farmyards. The ashes of such manure, it was suggested, were of easier conveyance, and that they contained those matters which our crops really needed. It is, however, a well-recognised fact, that the **organic matter** of farmyard-manure—which, by burning, would have been sent into the air as smoke—has **very important duties to discharge in the soil,** and for this reason it demands every care.

CHAPTER XXII.

HAVING indicated the various materials which plants require for their food, and explained the fact that these materials exist in all fertile soils, it now remains for some reference to be made to the way in which the plant secures these supplies. From what has been already stated it is clear that all solid particles of the soil must become dissolved in water before an entrance can be gained into the plant. This fact at once discloses to us another of equal importance—namely, that there is a difference between the soil and what we have termed plant-food. It is **the soluble portion of the soil** which is alone able to act as **plant-food**, and as a matter of fact this is only a **very small portion.** We may have in the soil an enormous quantity of matter composed of exactly the same materials as we need for plant-food, but still of no use whatever as food. This arises from the fact that it cannot be dissolved in water. That portion of the soil which can be dissolved in water containing carbonic acid, or other weak acid, is ready for doing duty as plant-food, and the searching and penetrating force of the roots of the growing crop favours the solution of any such plant-food which may be present in the soil. This is a most wise provision, for it holds in reserve the means for preserving the fertility of soils for future ages, and yet enables the industrious husbandman to secure abundant crops without injury to those who may come after him.

Let the fact, then, be distinctly recognised, that the soil consists of "**active**" matter which is **ready for immediate use,** and **another portion** which is **not ready** for use, but simply awaits a call to duty. This latter portion has been distinguished as the "**dormant**" or sleeping-matter of the soil. These two portions of the soil may be compared to the active and reserve forces in our army—the one being **ready for duty** and the other ready to **fill up the ranks** as vacancies arise. It would be imprudent to reduce greatly the strength of those on active duty, and make no provision for having some help in reserve. We often, however, see this done on the land, when **a bad farmer** adopts a system of cultivation which **completely exhausts its strength,** and leaves the land worn out and unproductive. He has done his best to make use of nearly all the active matters in the land, and done nothing to secure another supply being obtained from the dormant matter of the soil. He has **punished the land** by so doing, and in all probability he has **impoverished himself** also.

There are rocky substances which, by analysis, might be shown to **contain all the elements** of a rich and fertile soil, and in like manner there are many soils which would, upon examination, prove themselves to be possessed of a composition good enough for producing the best crops. In both cases the elements of fertility are present in equal abundance, but still may be **incapable of yielding a luxuriant crop** by reason of the **mechanical** con-

dition. No one would expect the rock to be productive, but many have expected **a badly prepared soil** to yield satisfactory crops. So far as regards the actual difference between that rock and that soil, it is far less than it is generally supposed to be. The fact has been sadly overlooked, that it is not the composition of the entire soil which shows its stores of plant-food; this can alone be known by an examination of the available portion of a soil. There was a time when farmers expected that an analysis of a soil would have shown them what it contained which would be of service for his crops, and also what was deficient. In this they were disappointed, because in making such analysis **the entire soil** was examined and the composition given regardless of the fact that only **a very small portion** of it was in an **active** condition. A soil might have had its active matter very largely exhausted, and yet have possessed boundless stores of wealth. What the farmer really wanted to know was, what there was in the soil which was in a condition **ready to act as plant-food,** and which his crops could make use of **in his next course of cropping,** or at any rate within a short period. That information he did not secure by the examination made, and the practice of soil-analysis soon ceased to be valued. Even up to the present time there have been very few analyses of soils which have been made upon a right and proper basis. Such analyses, to be of any use to the farmer, must in the first place distinguish between the active and dormant matters in the soil. They

must show the composition of each, and then the farmer will know what plant-food he has at his command for immediate use, as well as that which he possesses in his soil **as a reserve,** which he can **gradually bring into use.** As this mode of conducting the analysis of soils is adopted, so will farmers appreciate its value, and the practice will again become more popular than ever.

But the question naturally arises, **How can the dormant matter of the soil be brought into an active condition?** There are various agencies which contribute towards the attainment of this result. Of these, two or three are especially influential in carrying forward this work. The same natural agencies which have reduced our rocks into soil will, if they have the opportunity, carry forward their work, and make a portion of the dormant matter of the soil available for plants. With this object in view, soils should be exposed as much as possible to the air and frost. The **oxygen** and **carbonic acid** of the atmosphere at once commence their work; perseveringly and silently they work away at the soil, making small passages into its minute particles, and exposing fresh surfaces for the water to act upon. The **frost** follows, and in freezing the **water** in these little channels bursts these portions of the soil, and when a thaw follows it crumbles into still smaller particles. The oxygen and carbonic acid, ceaseless in their work, assist in rendering fresh matter soluble in water. As these solutions pass through the soil, they are arrested by other sub-

stances—especially the double silicates, and here they are held in a condition of safety, awaiting the time when they will have to be surrendered at the demand of the growing crop.

So also the fermentation of farm-yard manure and vegetable matter in the soil, contribute by their decay, to the decomposition of earthy matter which may be in close contact with them. The gaseous products of their decay—notably the carbonic acid and organic acids—carry forward the attack upon the surfaces of any particles of soil they come in contact with, and thus promote the change of dormant matter into an active condition.

The action of quick lime—which can here be only glanced at— also carries forward this same disintegration of the soil, and contributes towards the end in view. These are agencies which are all more or less within the command of the farmer, and by their aid he can gradually make good use of the reserves of fertility which too often lie in his soil uncared for and unknown. Treasures are thus locked up within the soil, and it is for the skilful farmer to turn these to his own advantage, producing by their aid more luxuriant crops, and keeping the soil in its highest condition of productiveness.

CHAPTER XXIII.

In comparing the composition of the mineral matter found in plants with the mineral matter

found in our **soils**, we find **one** body very generally present in the soil, which forms no portion of the food of our crops. This body is the **Alumina** of the soil. Although it forms **no portion of the plant-food** necessary for the structure of our cultivated crops, it has **other duties** devolving upon it which unavoidably associate it with the plant-food itself. Reference has already been made to the **double silicates** present in some soils; these are silicates of alumina and some second substance. The silica has **two partners**; the one (alumina) is **a permanent partner,** whilst the other may either be soda, lime, potash, or ammonia; and in consequence of the silicate having two partners, these compounds are known as double silicates. It may be as well to call to remembrance the fact, that when the double silicate of alumina and soda meets with lime in the soil, the soda is thrown out of the partnership and the lime is taken in, and the new product is a double silicate of alumina and lime. If this double silicate comes in contact with potash, then the lime is turned out, and the potash is admitted as a partner, and the new "firm" is known as the double silicate of alumina and potash. But if ammonia should be brought in contact with this double silicate, then the potash has to give place to the ammonia. Thus it will be seen that the **ammonia** is the highest favourite, the **potash** the second, the **lime** the third, and the **soda** the fourth, and a higher favourite always puts aside any other of lower rank.

At length a period arrives when another agency

is brought into action, and that is **the demand made by the growing plant.** The special power exerted by the delicate **hairs on the roots,** probably aided by some solvent agency exerted by the plant, induces the ammonia to leave the partnership and pass into the plant, whilst its place in the double silicate is soon taken by some favourite of lower rank, possibly potash. If the plant wants potash, it is very likely to tempt the potash also to leave, and enter into the plant. In fact **the powers of vegetable life** have a **commanding influence** over each and all of the **second rank** partners, and even if it wants silica its demands are yielded to. Now the **alumina** steadily declines to enter into the plant, possibly because it is neither asked nor wanted; at any rate it contents itself by doing the work of an "**out-door servant.**" Upon it devolves the duty of reconstructing the broken-up partnership, and this it persistently labours for. Thus the continued action of these double silicates depends greatly upon the action of the alumina, for to it may be applied the phrase "amidst the faithless, constant only she." From first to last favouritism and change characterise the action of these **double silicates,** but still they perform a duty of immense importance in acting as **purveyors of food** for the plant. Neither must it be overlooked that as guardians of those fertilising materials which come under their care, they discharge duties of a most important character. Hence we associate alumina with our consideration of plant-food, because it performs important duties in con-

nection with the guardianship and supply of that food, persistently carrying on the work of an "outdoor servant," steady to the trust devolving upon it. Nor shall we be justified in leaving this branch of the subject without acknowledging how greatly we are indebted to Professor J. T. Way for the important discoveries which have rendered us so intimately acquainted with the character and utility of the double silicates.

We must not, however, suppose that the double silicates are the only agents by which plant-food is secured for the purposes of vegetation, although they exert a powerful influence so far as regards the supplies of the alkalies and silica. Independently of the double silicates, the solvent powers of rain-water (aided by the carbonic-acid it gathers in its course) enables these and many other substances to be carried into plants.

The fact must not be overlooked, that plant-food is often seriously injured by the presence of bodies which are not suitable for use by the growing crop, or which may be present in too large a quantity. The protoxide of iron (ferrous oxide) is a substance which is unfavourable to vegetable growth. Almost every farmer has noticed the unhealthy character of some of the poor yellow clays, which largely owe their peculiar colour to the presence of this body. In many instances this substance is found in soils in a smaller proportion, as the exhausted remains of a body which has done good work for the growing crop. There is another

oxide of iron, known as the peroxide (**ferric oxide**), which is exceedingly **valuable** in promoting vegetation. When exposed to the atmosphere it absorbs ammonia from the air, and when it is again buried in the soil it yields up its accumulations to the growing crop; and in case of necessity it also gives up a portion of its oxygen; thereupon it takes the form of the lower oxide, and if it were present in any large proportion it would then exert an unfavourable influence upon plant-life. In the ordinary course of cultivation, when the land is again ploughed, it is brought to the surface, or within reach of the air, when it again secures its full supply of oxygen, and thereupon becomes valuable to vegetation. This change has doubtless been observed when a **yellow clay** has been ploughed up before winter, and well exposed to the **air** and **frost**; for in such cases the oxide of iron will take the higher form, and become **changed** from an **injurious** substance into one which is very **beneficial** in promoting the fertility of the soil.

Some of the **organic acids** which are formed in the soil, by the decay of vegetable matter in the **absence of a sufficient supply of air**, are unfit for taking part in the nutrition of plants, and they interfere with the use of plant-food which is prepared for that duty. Here again the exposure to the **oxygen** of the atmosphere, or the passage of air through the soil (as, for example, by the drainage of the land), **corrects the evil**, and the injurious matter

takes a more highly oxidised form, becoming thereby useful and valuable.

In like manner we occasionally find the soil injured by the presence of too much **salt**, or other saline matter, which by reason of its abundance exerts a prejudicial influence. These cases generally occur when the drainage is very imperfect; but when this has been rectified, the passage of **rain water** through the land gradually corrects the difficulty by **washing the objectionable matter away.** For a time, however, the plant-food in the soil is prejudiced by the presence of these undesirable substances, and it is therefore necessary that their condition should be **modified**, or that they should be **removed** from the soil.

CHAPTER XXIV.

THE growth of a crop necessitates a supply of the materials built up in it, just as much as in the building of an ordinary house we must have a proper supply of the several materials found in its walls, floors, doors, windows, etc. We see the completed **house**, and a skilled surveyor will soon prepare **a list of the materials** necessary for its building.

So also the analytical chemist can examine a **crop**, and prepare a list of necessary materials. On page 102 such statements have been shown as to the materials needed by certain average crops of wheat,

beans, turnips, and clover. It would be easy to supply similar lists of materials needed for all other crops, but those which have been given will serve as examples. If a crop be grown on a field we may be sure that the ground has supplied to it the inorganic materials it contains; and in giving up these supplies the land has a so much **smaller** store remaining in it. A builder who was drawing upon his stores for the house he is erecting, sooner or later finds some one or more of his **stores exhausted**, and when he secures a fresh supply all proceeds satisfactorily. So also with the growing crop: the demands made upon the soil frequently cause a short supply of some of the materials. Its growth is consequently checked, there is an inferior crop, and we say **the land is exhausted.** It is not meant by this that the land has no plant-food in it, but rather that **the supply of plant-food** required for that particular crop is **imperfect.** Another crop might possibly be grown very perfectly, because its requirements were fully supplied. Exhaustion of the soil is often limited to an **inability to produce certain crops,** whilst it may still be **capable of producing other plants.**

Such exhaustion of the soil may arise from the supply of **one body** being insufficient; and in such a case the fact of that single deficiency determines the productive power of that soil. Hence we have the rule that it is that **necessary material** which is present **in the least abundance** which determines the fertility of the soil. If, for example, the

phosphoric acid had been exhausted, the absence of this body prevents the land being fertile. It would not help matters for a large supply of every other necessary material to be added, as the growth is stopped for want of something else, and until it is supplied the land cannot be fertile.

It is a very common idea that wheat is one of our most exhausting crops, and the growth of two white straw crops was for a long time forbidden in many districts for this reason. If we compare the demand made upon the soil for a crop of **turnips** with the requirements of a crop of **wheat,** we see a very marked difference in the materials used in the two cases.

	One Acre of		
	Turnips.	Wheat.	Clover.
	lbs.	lbs.	lbs.
Potash . . .	201	25	52
Phosphoric Acid .	59	19	20
Sulphuric Acid .	79	6	13
Chloride Sodium .	66	½	...
Lime . . .	107	10	111
Soda . . .	39	2	7

In like manner **clover** makes demands in excess of **wheat**; and hence it is that we more often hear of land being **tired of clover,** and **failing in turnips,** than being unable to produce wheat. If the demands upon the soil are in advance of the supply, exhaustion shows itself in some form or other. It needs a prudent and intelligent management of

the soil to **avoid making demands** upon the land, which have **not** been previously **provided for.**

A distinction must be drawn between an Exhaustion of **the Field** and an Exhaustion of **the Farm.** If, for example, a heavy crop of clover were grown upon a certain field and removed for sale in the market, the field and the farm are **both exhausted** of certain fertilising materials. If that crop of clover had been taken to the homestead and consumed there, although the field would have been drawn upon for the materials in that crop, the farm would not have been impoverished thereby. It would be simply a case of transfer from one part of the farm to another. Still the field must not be overlooked in the restoration needed, because the crop remains upon the farm, for in such a case the productive powers of that field would decrease.

It is sometimes thought that the first and the greatest care to be taken in the management of the land is **to avoid exhausting the soil**; but it would be more correct to look upon the **plant-food** existing in the soil, as so much working stock **rented** from the landlord, which, by frequent use, shall yield a more **valuable product,** and thus enable **the temporary loan** to be repaid. If the finished farm products can be sold for £20, £30, or £40, and the loan from the soil can be replaced for £2, £3, or £4, the more rapid and the more extensive the transactions, the better for the occupier and for the owner. The success of the system very mainly depends upon the **return** to the soil of **the materials it needs.**

It would be easy to make an expenditure of the money in the purchase of some kind of manure; but if the supply so obtained did not meet the necessities of the case, the land would become exhausted, not because it did not receive manure, but because the manure was not suitable in character, and did not supply the deficiency. As our knowledge of the composition of our soils becomes more complete, we shall be better prepared to determine what must be added to the soil to repay that portion of the loan which the land needs.

It must ever be remembered that as a matter of economy it is unnecessary to return to any field all the materials removed in our crops. The great bulk of our soils consists of materials which are waiting to be brought into active service, and it is manifestly unnecessary to purchase a supply of these materials. To do so might be very easy, but it would be very extravagant. It would be as if a farmer who had the necessary corn in his granary, sent to a neighbouring town to purchase what he wanted, rather than use the granary key. Much of the loan made by the soil may thus be restored, with many other advantages than simply saving a needless expenditure of money. There will still be some deficiencies to supply, and in the prudent purchase of the necessary materials there will be room for much skill and judgment.

An active cultivation of the soil and the production of large crops are perfectly consistent with—and are in fact dependent upon—the maintenance of the

land in a high condition of fertility. Exhaustion of the soil will be avoided by making **the reserves** of fertility in the soil **useful for plant-growth,** and by supplying any **deficiency** still unprovided for by means of **manures.**

CHAPTER XXV.

THE primary object in view in the use of **manures** is to supply the soil with any **plant-food** of which it may possess only **an imperfect store.** The cultivation of our various crops causes a considerable quantity of matter to be **removed from the soil,** and if these crops are taken away from the land it is perfectly clear that the soil must be **impoverished** by so doing. Knowing as we do the composition of our various crops, we can form a tolerably accurate opinion as to the **actual loss** which takes place. It is well known that if the removal of the crops grown, be continued for any length of time without proper remedial measures being adopted, the soil ceases to produce remunerative crops. Hence it is that manures are applied to the land **to make good** as far as possible any injury sustained by the soil in the growth of crops, and if practicable to increase its productive powers. It will be seen that the manures in general use contribute in a variety of ways to the attainment of these results. **Farm-yard manure** takes a pre-eminent position in the entire group of

bodies employed as manures. The evidence of practice is strong in its praises, and long continued experience shows that when it has been carefully managed it is of great value to the land. A moment's consideration shows that as it largely consists of vegetable matter—portions of crops which have been grown upon the land—so by its return to the soil we are giving back to the soil some of the same materials that were taken from it by the growing crops. Other portions of the same crop may have been sent away to market, or otherwise disposed of; here, however, we have some of the actual matter taken from the soil, and by returning it to the land we may be satisfied that we are at any rate returning some of the materials drawn from the soil. It need not therefore cause any surprise that this is a practice which experience shows to be good.

In the growth of a crop of wheat we draw from the land, in an average crop, about 25 pounds of mineral matter in the corn, and 150 pounds of mineral matter in the straw per acre. We may assume that the corn is sent to market, and the mineral matter it contains goes away from the farm; but if the straw becomes converted into farm-yard manure, the 150 pounds of mineral matter is, or ought to be, returned to the soil. Now what is still more important than the fact of this weight being returned, is the return of the same materials in all their original variety. It would be possible to return another 150 pounds of mineral matter, but this would not be as generally

effective unless the same varied composition could be secured, and even then it would be impossible to secure its distribution through the soil under equally favourable circumstances. The farmer is perfectly justified in giving farm-yard manure a position in the front rank, for it is worthy of his very best care.

The growth of a crop should be regarded as a loan made by the soil for a temporary use, and in the return of farm-yard manure to the land some portion of that loan is repaid. It is more satisfactory, because it is a return of a portion of that actually borrowed, and not some substitute which may not be equally suitable. Some portion of the loan made by the soil cannot be returned in its original form, because it has gone to market; but for this some good substitute must be found. The soil, like any other lender, likes its loan returned with interest, and in proportion as this is done with a liberal hand, so will it be the better prepared to make new and larger advances. It is therefore wise to regard all vegetable produce as carrying away a portion of the freehold, and that farmer adopts a prudent policy who takes care that the loan made is liberally repaid. Circumstances will, however, arise in which it is very advantageous to sell both corn and straw; and the question frequently arises, Will the land be injured if some other fertiliser should be purchased instead? The result entirely depends upon the character of the fertiliser substituted. Prudently carried out, the substitution may often be advantageous; but it must be remembered that a

great variety of substances have been removed, and if only a small portion of these substances should be returned, a deficiency may still remain in the soil which will certainly decrease its productiveness. It is not that material which is most abundant in the soil which regulates its fertility, but that essential for growth which is least abundant. It is because the farm-yard manure contains such a great variety of fertilising substances, that it is so generally valuable. If, therefore, straw is sold from a farm, it becomes additionally necessary to take care that in repaying the loan to the land all the requirements of the soil are provided. Certain portions of all our cultivated crops are regularly removed from the farm, but the more fully this is carried out the more necessary does it become, to arrange that the soil suffers from no deficiency in consequence. It must always be remembered that as "the weakest link in a chain is the measure of its strength," so when the system pursued involves a very large substitution of fertilising matter, great care must be taken to strengthen the weak points of the soil. The addition of unnecessary matter does not meet the difficulty, for unless a supply of the most needful substances be given, the money value may be applied to the land without giving to it the power to yield abundant crops. In brief, it may be stated that a departure from the custom of carefully returning to the soil the usual supply of farm-yard manure, necessitates additional care in providing for the land a complete substitute.

The fertilising power of farm-yard manure is by no means limited to a return of much of the same mineral matter as was taken from the land. We also gain the important advantage of having that mineral matter very perfectly **distributed through the soil.** No mechanical arrangement could accomplish this result equally well. It has the further advantage of yielding up its supplies **gradually,** and at different periods in the plant's growth. As the farm-yard manure lies in the soil, its decay goes on more or less rapidly, according to the character of the soil in which it is buried. As that decomposition proceeds, so the mineral matters built up in its structure are released from their bondage, and **a mixed food** is again presented to the plant similar to that on which some preceding crop had fed. Not simply **one or two** substances, but **a complete series**; not one to-day and another the following week, and so on; the plant-food on which some previous crop fed is presented without any absentee interfering with the progress of the plant. Punctuality in the supply of plant-food is as important as it is in the affairs of everyday life. Work has to be done which needs the concerted action of eight or ten individuals; if some are ready whilst others are absent, little progress is made in consequence. It is the same with vegetable growth; if all the requirements are provided, the plant progresses favourably; but when it has to **wait first for one** material, and **then for another,** its growth is unavoidably checked. In rightly appreciating the value of farm-yard

manure, this **gradual** supply of food of a tolerably **complete** character will be found to be one element in its nature which has materially aided it in gaining the warm approval of experienced men.

CHAPTER XXVI.

THE important duties discharged by farm-yard manure are further influenced by the care taken in its proper **preservation.** If during the decomposition which it usually undergoes, any **waste** be permitted, it is evident that such waste **decreases** the **repayment of the loan** of materials received from the land. In some farm-yards we still see black drainage matter flowing away from the manure,—an occurrence which every man of experience knows to be a distinct loss of fertilising matter. The decomposition of farm-yard manure which is so very commonly adopted, is desirable and proper, provided it be rightly regulated. It is a means whereby the **vegetable matter** becomes altered in its character, and the **mineral constituents** which have been utilised during the plant's growth are **set free** from their bondage, in a condition ready for again becoming useful for the growth of some other plant. Much of this mineral matter becomes **soluble** during the changes which take place in the fermentation, and is in solution in the **black streams** referred to, this plant-food is often allowed to **waste.** Such

management rather corresponds with the action of the careless spendthrift than that of one who carefully husbands his resources to repay a loan he has contracted. This, at any rate, is not the way to repay to the soil the plant-food which has been borrowed from it. In all well-constructed farm-yards, arrangements are made for conveying all the drainage matter into **a tank,** or some convenient receiver, from which it is pumped out for use. No portion of the manure should be allowed to **waste,** for it necessitates the **purchase of new supplies** to enable the farmer to return to the soil that which he has removed in his crops.

Some farmers have to contend with the disadvantage of **large open yards** which receive large quantities of **rain,** and have no conveniences provided for the preservation of this liquid manure. What is a man to do under such circumstances? In the first place let him **realise** the fact of **the loss** which he sustains. His position is undoubtedly one of great difficulty, but he gains much by knowing that he is losing fertilising matter, which he must replace in some form or other if he would maintain the land in fertility. Being aware of his loss, he will be sure to do the best he can to get the aid of his landlord to **prevent it.** No farm can be considered in a tenantable condition whilst such losses are not guarded against, and a suitable tank should be constructed. When the waste has been stopped, he will soon find means for using the **liquid manure,** and especially by having it **pumped**

over his manure heaps from time to time. In some cases, even this use of the liquid will not take all that he is bound to dispose of. He will in such instances see that this arises from the rainfall which reaches his yard being greatly in excess of that which is desirable; he will prudently adopt measures for carrying off as much of the rain-water as possible before it reaches his manure, especially all that falls upon his buildings, and it will ultimately make him value the advantages of properly protected yards. So long, however, as he has to contend with excessive supplies of water, it is probable that the use of such liquid for irrigating land at a lower level will be the best mode of using any superabundant flow of liquid manure not required for the manure heaps.

The care which may be taken for the preservation of farm-yard manure from waste by any addition of water must not be carried to the opposite extreme, so as to lead to the practice of keeping the manure short of its necessary supply of moisture. The adoption of covered manure pits and covered yards, although having many advantages, is still open to the danger of allowing the manure to become too dry. We have noticed the disadvantages arising from an excess of water, and it may be well to point out the losses arising from a deficient supply. It is, as a rule, desirable and necessary that farm-yard manure should undergo a proper fermentation. During the changes which then take place a moderate supply of

water is essentially necessary, for if there should be **a deficiency,** the manure becomes overheated, or, as it is commonly termed, fire-fanged, which probably means a sort of burning. Looking at the changes from a chemical point of view, we can confirm the popular idea of injury arising from **too much heat.** We may, however, go beyond this, and point out that the loss which takes place is most serious, in consequence of the **escape of ammonia** from the manure. **Ammonia** may be produced in farm-yard manure in **two distinct forms.** It may be associated or **combined with** decaying vegetable matters in forms which are known as **organic acids**; and in this condition, whilst it **may be washed away** by water, it cannot, at any ordinary temperatures, be drawn away into the air, or, in other words, it is **not volatile.** If, however, these **organic acids** have, by reason of a scarcity of water or otherwise, **changed into carbonic acid,** and have combined with the ammonia in this form, then **the ammonia is exceedingly volatile,** and passes away into the atmosphere with the greatest freedom. It will therefore be evident that it throws a very serious loss upon the farmer when the ammonia of the farm-yard manure takes this light and volatile form. It then passes beyond his influence and control, becoming about **as useful to his neighbours as to himself.**

The means whereby the fermentation of farm-yard manure is regulated are exceedingly simple, but at the same time very important. Apart from the

question of the composition of the manure—which we do not here consider—we find that the supply of **air** and **water** have very **controlling influences** upon the rapidity of the fermentation and the character of the products which result therefrom. If **air** be **excluded** from the manure, the **fermentation** is proportionately **checked,** whereas it is quickened by a proper admission of air. This is commonly recognised in practice, for if we wish to **hasten the fermentation** we have the **manure turned** and thrown together **lightly** in a heap; but if we wish **to check the fermentation,** horses and carts are allowed to pass over it, so as to **compress** it as much as possible. In the one case the air is freely **admitted,** and in the other instance it is **excluded.** We have a very similar set of circumstances in the case of an ordinary **fire**; if you desire it to **burn more rapidly,** it is stirred and poked so as to **lighten** it, thereby enabling more air to be admitted. If, on the other hand, the desire be to **check the fire** in its burning, the coals would be kept compactly together, and probably the surface would be covered with small coal to **impede** as much as possible **the passage of air** through the fire. In the same way with the farm-yard manure, the rapidity of **fermentation** is very greatly **under control,** and it can be hastened or impeded at will. It is very well known that there is a very great difference in the manure from different portions of the live stock, some of which is naturally very slow in fermentation. At first this appears to be an

exceptional case, so far as regards the influence of the air in making the fermentation very rapid; but even here the same general rule will be found to apply, as soon as the decomposition has fairly commenced.

CHAPTER XXVII.

THE fermentation of farm-yard manure is also materially influenced by the quantity of water present in the manure. It has been already stated that when there is a **deficiency** in the supply **of water** we have the ammonia formed in combination with carbonic acid **(as carbonate of ammonium)**, and consequently in a **very volatile** form. Moderate applications of liquid manure pumped over the heap from time to time, so as to **keep the manure moist**, will secure a fermentation of a temperate character, and the **ammonia** will then take a safer form, because it **will not be volatile.** When the fermentation is made **rapid** by the admission of air, it then becomes more than ever necessary to keep that fermentation of a proper character, by **the controlling influence of moisture.** Wherever manure is kept in covered pits or covered yards great care is necessary to preserve it in a moderately moist condition, otherwise the **form of loss** is simply **changed**; for in the one case it would be **washed out** of the manure heap, and in the other instance it would be **sent into the air.**

The degree to which this fermentation or rotting

of the farm-yard manure should be carried depends very much on the circumstances of the case. As a rule, the manure which is intended for **clay soils** and clay loams, is applied to this class of land in a tolerably fresh condition, and when it is only **moderately fermented.** The reasons for using it in this condition are the general **safety** with which the decomposition proceeds **in such land,** and also because of the mechanical influence of the manure in making these **soils more open** and porous. When the application is made to **light lands,** the general rule is to apply the farm-yard manure in a **thoroughly decomposed** condition, so that the land **may not be made more open** in its character. Further than this, as the sands and sandy loams have very limited powers for preserving fertilising matter from **waste,** it has been thought desirable to have the farm-yard manure **fully prepared for use** by the plant before it is added to the land. No doubt this has **involved very great losses** by the washing away of much fertilising matter before the plant is able to make a good use of it. There is therefore considerable difference in the degree of fermentation to which farm-yard manure is subjected so as to secure it in the most suitable conditions for all kinds of soils.

This difficulty has long been felt in reference to the use of well rotted farm-yard manure upon light lands, which had **little power of retaining** the soluble matter contained in **the manure.** A very marked economy has resulted from applying it to the

land when it was carrying **a crop capable of rapid growth,** and thereby quickly changing this manure into vegetable matter. **The clover crop** has been preferred for this purpose, and the manure has been applied at various periods of its growth, according as it best met the system of farming pursued. The result secured in each case would be **changing** the farm-yard manure **into a living crop,** and afterwards making those **crops yield plant-food to the soil.** In this way the usual **waste** arising from the fertilising matter being washed out of these sandy soils has been **prevented** by the intervention of an active growing plant. Many of our soils possess special absorptive powers, and are quite prepared to preserve for vegetation any manures entrusted to them; but when we have to deal with soils destitute of these powers then some other **guardianship becomes desirable.**

Whenever farm-yard manure is **applied upon the surface** of a growing crop, it is, with very few exceptions, desirable that it should have been thoroughly **well fermented,** and reduced to a soft and blackened condition. When this has been carefully carried out the **ammonia** has been secured in a **non-volatile** condition, and consequently the manure suffers little loss from exposure to the sun. It is also more quickly secured within the growing crop, and this is a matter of considerable importance. It is worthy of notice that when this system of using farm-yard manure is carried out, and **a guardian crop** is made use of to compensate for the defects in the

natural absorptive powers of the soil, care must be taken that the manure shall ultimately serve the purpose for which it was originally intended. It is no uncommon thing for farmers to be unable to grow wheat on some poor light soils, without some farm-yard manure being applied for the wheat, much of which, by reason of the non-retentive character of the land, is lost. In such a case as this, supposing the preceding crop to be clover, if the manure had been put upon the clover and taken up by it in a quick growth, we should have much of the manure transformed into clover plant. This being ploughed into the land would, of course, by its slow and steady decay, yield that manure to the wheat plant progressively, and the wheat would be as fully advantaged as if the soil had acted as the guardian of the plant-food supplied. Supposing, however, that manure had been applied to a younger clover plant, and much of the produce removed, the circumstances of the case would be materially altered. It may be that the change would be more profitable, and under some circumstances more desirable; but in such case it is well worthy of consideration how far the clover crop has acted as a guardian of the plant-food for the wheat, or yielded direct profit to the cultivator of the land. There are many cases in which this would undoubtedly be a most desirable course of procedure; but so far as regards the repayment of the material borrowed from the soil, the result would certainly vary considerably according to the course adopted.

However desirable it may be to a farmer to rent land which is in good condition, his only advantage therefrom is to keep that fertilising matter in active circulation. At one time he borrows from the soil; at another time he repays the loan with interest; but he ought to be able, in doing so, to leave for himself some profitable advantage by the transaction. He wants to keep up a series of these loans and repayments; but for his own sake he should be careful to let repayment always follow a loan, then he will keep the land in a satisfactory condition for making more profit on the exchange. Let farm-yard manure be regarded as a part repayment to the soil of what the growing crops have drawn from it, and this will go far to confirm the importance now attached to farm-yard manure by men of lengthened experience. To neglect the proper care and extended production of this manure, simply because artificial manures can be easily obtained, is neither fair to the land nor for the advantage of the occupier.

CHAPTER XXVIII.

As this manure consists of excrement of the live stock of the homestead, intermixed with straw or other materials used as litter or bedding for these animals, it is evident that the composition of such manure must take a very wide range, according to

the conditions and circumstances under which it may have been produced. It is, in the first place, clear that **the food** which the animal consumes must influence the character of **the excrement.** For instance, that produced from a food containing a large proportion of nitrogenous matter—as corn or cake—would be very different from the excrement of an animal living entirely upon straw, which is chiefly carbonaceous matter. In the next place, **the age and character of the animal** making use of the food must cause great variation; for, whereas a full-grown animal would only abstract from the food materials for replacing the waste of the body, **a growing animal** would also require the structure of its body to be built up from the several ingredients of the food. In the case of the growing animal, it would largely **impoverish the food** it received, by drawing from it matters for the development of its **skeleton,** its muscles, its tissues, etc. In the former instance, the matured animal would separate very little, if any, of the phosphate of lime for the formation of bone, and considerably less of the nitrogenous compounds from which the fleshy parts of the body are formed. When an animal has become so fully matured that there is a general cessation of growth, then—although there would be a transfer of some of the elements of food to restore the waste of the body—there would be little more than an exchange of the same elements, except so far as related to that portion of the food used in the respiration. In general husbandry such cases of

fully matured animals are rare; for if we except some of our horses, all other kinds of farm stock may be looked upon as growing stock. In the case of a **full grown horse** which is engaged in hard labour, the food is necessarily rich in nitrogenous matter, such as we find in hay, beans, oats, etc., and this portion of the food is used in the system for replacing **the waste of the body** arising from the labour performed. Here, then, we have a large supply of nitrogen in the food, and in exchange for this we find a large quantity of nitrogen in the excrement. If we take the case of **a young horse** employed in work, it has not only to replace the waste of the body caused by its labour, but it is also desirable that it should increase its muscular growth **and its skeleton.** The natural consequence is, that the young horse retains in its system both nitrogenous matter and phosphate of lime; hence, in these respects its excrement is poorer than that obtained from older horses.

Let us take another instance, that of a **dairy cow.** It may be fully grown, and therefore have no direct need for anything more than any other fully matured animal; but if she is **yielding milk,** or **nourishing a calf,** although she does not need additional supplies for herself she does require them for the performance of the work which devolves upon her. The result of this is a demand upon the food for a considerable supply of the materials which build up bone, muscle, fatty tissues, etc., and **the excrement** is therefore **very poor.** It also possesses

another important variation in **the larger quantity of water** which it contains, consequent upon the necessity for softer and moister food for animals which ruminate, or chew the cud. These cases sufficiently illustrate the **variations in the excrement** of different kinds of live stock, and show why the manure of the **horse** is highly charged with **nitrogen,** as well as the reason of the manure from the **cow**-shed being **poor** and of a **watery** character. There are several other conditions which influence the character of farm-yard manure, such as the proportion between the **straw** or litter used and the **food** consumed, and the quantity of each.

For these and various other reasons, it will be seen that farm-yard manure is **most variable in its composition**; hence it is a matter of considerable difficulty to take any chemical analysis which shall indicate the average composition of this manure. But whilst we need not take all the details of its chemical analysis, it will be instructive to state **the materials** usually **found** in farm-yard manure: Water—soluble organic matter (containing nitrogen) — soluble inorganic matter—silica—phosphate of lime — lime — magnesia — potash — soda — chloride of sodium — sulphuric acid — carbonic acid — insoluble organic matter (containing nitrogen) — insoluble inorganic matter.

There is, it will be seen, a very **great variety of materials** in farm-yard manure, and hence its **general utility** for all crops and for all lands. It rather reminds one of the long prescriptions which in

olden times were so successful amongst patients; for out of the variety of drugs employed, **some** at least were likely to be **wanted.**

An investigation was carried out by Dr. Voelcker[1] to determine the changes which took place in farm-yard manure during a carefully-conducted fermentation, and the general result may be shown by the differences in the composition of the manure before and after such fermentation:—

	Fresh Manure.			Well rotted.		
	Cwt.	qr.	lb.	Cwt.	qr.	lb.
Fertilising substances . .	0	1	19¾	0	1	19¾
Other materials, chiefly organic matter	6	1	10	4	1	27
Water	13	0	26¼	15	0	9¼
	20	0	0	20	0	0

We see from this that the more **active fertilising substances** formed only about **48 pounds in a ton,** and that to make use of these we have to cart about and work from 13 to 15 cwt. of water, and from 4 to 6 cwt. of materials of little market value. It is not to be wondered at that these figures led some to think that, after all, farm-yard manure was greatly over-estimated by farmers. Taking the more active fertilising substances in each ton at their market value, they amounted to about 13s.; but it is also certain that much of **the value of farm-yard manure** depended upon the fact already referred to, that there was a **great variety in the supply.**

[1] *Royal Agricultural Society Journal*, vol. xvii.

The day will doubtless come when some of these **ingredients** which are **now regarded as valueless** will be more correctly estimated, so far at least as regards the effects they produce upon the growing crop. The complete character of plant-food has not as yet been sufficiently recognised; but when it **shall be rightly valued,** it will tend to explain why it is that farm-yard manure has established such a high reputation.

CHAPTER XXIX.

IN considering the character and influence of farm-yard manure in relation to the soil, we shall seriously err if we limit our attention to the **mineral** matter it contains. In addition to these very valuable fertilisers, we find in this manure **organic** matter, which discharges distinct duties in the soil. These **organic matters** are grouped into **two classes,** according as they may or may not contain nitrogen, and hence they are known as **nitrogenous** and **non-nitrogenous** bodies respectively. These have very distinct duties to perform in the soil, and they also take different parts in the fermentation of the manure. **Nitrogenous bodies** are not only very much disposed to **encourage** those decompositions—or changes—which we know by the terms **fermentation** or rotting, but they **induce other bodies** to take part in these changes also. This is quickly

observed in the manure from stables, which has already been described as containing much nitrogen. The first evidence we have that decomposition has fairly started is the **increasing heat** of the manure; for although decomposition may have commenced in the excrement before it gets mixed with the straw or litter, we soon observe a marked increase in the changes so begun. It very quickly induces the straw to join in the decay, just as one rebellious subject induces others, who may be naturally disposed to be quiet, to become unsettled and desirous of change. In this case, however, there are distinct advantages to be gained by the decomposition of the straw, and the carbonaceous matter it contains is able to render good service in the fermentation.

It may here be somewhat more fully explained than has already been done, that the **straw,** or other litter, as it decays gradually loses its colour, and ultimately becomes of a dark or blackish colour, which is due to the **carbon**-aceous matter it contains entering into new combinations, forming organic acids and organic colouring matters. In the decomposition of straw the carbonaceous matter it contains becomes changed into a sort of sour, peaty mass, which contains several **solid** substances which are known as **organic acids.** They are called acids because of their sourness, and they are known as organic acids because they are formed from organic matter. There is a large number of these organic acids, each differing slightly in composition from the others; but of these two may be specially mentioned,

and these are **humic acid** and **ulmic acid.** When these come in contact with ammonia they combine with it, and they form **humate of ammonia** and **ulmate of ammonia** respectively. They are of a **blackish** colour, and are often dissolved in the **black liquid** which drains from heaps of farm-yard manure. When **ammonia** has entered into either of these alliances, it **ceases to be** of that **volatile** character which it possesses under some other forms.

When the decomposition of straw goes forward with **too little water** present, the **carbon**-aceous matter takes the form of **carbon-ic acid,** and this uniting with ammonia forms **carbon-ate of ammonia.** In this form the ammonia is **very volatile,** and pungent to the smell, as is well known in the strong smelling salts sold by druggists. Thus we may have the **ammonia** of farm-yard manure **produced in two distinct forms,** the one being **volatile** and therefore easily passing into the atmosphere, whilst the other is **not volatile** and does not fly off into the air.

The **nitrogen-ous** matters in the farm-yard manure, whilst they cause the carbon-aceous substances to undergo decomposition, also become changed themselves, and as a result of this we have **ammonia** formed. The great advantage of both undergoing decomposition at the same time is that we have the opportunity of so regulating the fermentation, by the presence of a **moderate supply of moisture,** that we can secure the ammonia from

loss by letting it unite with some one of the organic acids. Even in this form the ammonia is not safe, for if we allow an excess of water, by rain or otherwise, to fall upon it, then the ammonia may be washed out of the farm-yard manure, as we too frequently see in the black streams running from it.

Thus, in carrying on the fermentation of farm-yard manure, there is a liability to loss unless proper care be taken. When this fermentation takes place in the soil, the question of loss entirely depends upon the character of the land. If the soil is strong, and contains a fair proportion of clay, it is generally possessed of sufficient absorptive power to hold the products of the decomposition without loss. On such soils practice has shown that unfermented manure may be advantageously applied, and the decomposition goes on with safety. When the soil does not possess this holding character—as in sandy soils for example—then such lands cannot be regarded as safe custodians of the farm-yard manure; and experience shows that for such lands the manure should be carefully prepared for use before it is entrusted to its care.

It is worthy of notice that when the soil is of such a character that it can be safely trusted with the manure in only a slightly fermented condition, the soil is indirectly improved by the decomposition of the manure taking place in it. The chemical changes going on in the farm-yard manure often

extend to the surrounding earthy matter, and thus some of it is brought from a **dormant** condition into an **active** state, ready for being used as plant-food. The fermentation of farm-yard manure is never carried out to such an extent that the work is completed before it is added to the soil. In practice, it is always applied in a more or less unfermented condition, and there are thoroughly good reasons for the variations observed, to some of which reference has been made. It is, however, evident that the fermentation of farm-yard manure is an operation demanding careful management, as there is **great danger of loss** if proper care be not taken. At the same time **the means for controlling it are excessively simple,** and need little more than ordinary care in their adoption. The presence of a moderate amount of moisture has been shown to be of immense importance, but the opposite extreme must be guarded against. It is with this manure as with ourselves; for we naturally desire to avoid thirst by moderate supplies of liquid, and the greater the activity of the individual the more beverage is necessary, but in no case is such a quantity desirable that the person shall be thoroughly saturated by the supply.

CHAPTER XXX.

THE judicious employment of farm-yard manure cannot be looked upon as of less importance than *its* economical production and careful management,

especially when we consider the influence which it exerts on the produce of the land, and consequently upon the profits of the farm. The evidence of practice is agreed respecting its great value, and the improvements which have been introduced into agricultural practice have a powerful and direct tendency to increase the quantity and improve the quality of this product of the farm. If, however, we appeal to practice alone for an answer to the inquiry, What is the period of the rotation and the best time of the year for applying farm-yard manure to the land? we see an apparent conflict of testimony. It will at first appear to be almost impossible to elicit such a reply as will enable us to establish any definite rules. We see the usual practice varying greatly in different districts; but this need not occasion much surprise, for it is clear that as the conditions of soil and climate vary, so these must be met by corresponding modifications in our proceedings. In explaining this diversity of practice, we shall endeavour to indicate the circumstances which influence the course which is most desirable.

The most important consideration which guides the application of farm-yard manure is the power of the soil to hold manure. In this respect there are very great differences observable in land, and hence an experienced farmer is generally able to form a correct judgment in this respect. As a rule, this is chiefly determined by the proportion of clay which is present in the soil: and by this the judgment of the majority of persons is usually guided.

But it has been shown by Professor Way that the general mass of the clay does not take part in this work, and that some bodies associated with the clay really discharge this duty. These bodies are known as **the double silicates,** and may be regarded as **a modified form of clay,** rarely existing in clays in a higher proportion than 4 or 5 per cent. Hence the first lesson we learn from this fact is, that although the judgment is generally guided by the proportion of clay in the soil, 95 or 96 pounds out of every 100 pounds take no part in the work. Still the proportion of clay becomes a rough and ready means for forming an opinion on the subject. Incidentally, it may be mentioned that an increase in the percentage of these double silicates would be the means of making other soils capable of holding manure which do not at present possess this power, because they contain but little clay. If we have to deal with **soils which will retain the manure** applied to them, we have the satisfaction of knowing that we may use that manure just **when it best suits** the requirements of **crops** and the convenience of the **cultivator.**

The exceptional difficulties arise when we have to guide our proceedings by other considerations than these, and have to do our work so as to reduce as much as possible the loss which arises from waste taking place in the soil. We can entrust farm-yard manure to good holding soils, and allow fermentation *or* decomposition to proceed in them without any

fear; but this **cannot be safely done** in other soils which have **little power of absorbing** and retaining manure. This distinction in **the guardian powers** of the land naturally divide our soils into **two distinct classes**, one of which **may be safely trusted** with manure, and **the other cannot.** It will be seen that the difficulties are chiefly associated with the latter class, and we observe in practice various efforts made to meet these difficulties. Reference has already been made to some of them. The preliminary preparation of the farm-yard manure is generally carried out as fully as possible before it is ploughed into light and non-retentive soils, because thin soils cannot take care of the manure whilst it is undergoing this preparation. When it has been so fitted for immediate action, if it has to be ploughed in, that of course must take place before the sowing of the seed. Some time must of necessity pass before the young plant has become sufficiently developed to make any large use of the manure, and during this interval waste is in all probability taking place. Farmers do not need to be reminded of a fact with which many are far too painfully acquainted, but still it shows a difficulty which has to be met. Hence it is that well-fermented farm-yard manure has been so advantageously applied to the **clovers upon these light soils**, securing the manure from loss by the aid of a quick growing plant prepared for full and immediate action, and being again converted into a manure which would become slowly available for plant-food.

We may now notice two of the modes of applying farm-yard manure upon strong retentive soils, viz. spreading between the ridges, which are then split so as to cover it up, and a general spreading over the land, after which it is ploughed in. The objection to the former practice is the less perfect intermixture of the manure with the soil. As a rule which has few if any exceptions, **the manure** is rendered more effective by being **thoroughly distributed** throughout the soil. By this course of procedure a better action upon the soil is secured, and **the conditions of plant-growth are more perfect.** It is undesirable for the manure to be kept in separate lumps or masses; on the contrary, every effort should be made to have it thoroughly mixed with the soil. The more we know of the **delicate** character of the supplies of **plant-food,** the more shall we recognise the desirability of those supplies being **purified by the action of the soil** from all rankness of character. Apart from which, the distribution of manure throughout the soil has a tendency to utilise some of the plant-food of the soil, and a more complete and perfect supply becomes available for the plant. Nor must we overlook the increased fertility of the soil, arising from its dormant and inactive portions being rendered active and ready for use as plant-food by this contact with the decaying farm-yard manure which is used.

The cases are somewhat **exceptional** in which farm-yard manure can be applied **to corn crops,** in *consequence* of its tendency to encourage the growth

of too much **straw,** which endangers the yield of corn. In the **bean crop** we have an exception, and for this crop it is often employed; for when the growth becomes too luxuriant, and the lower blossoms fail in consequence, we have the means of stopping the injury by **topping the plants** with a reaping-hook. This stops the growth of haulm, and the pods soon begin to fill. The use of farm-yard manure is largely restricted to green crops, such as our root crops and clovers. These are the chief conditions which regulate the use of farm-yard manure, but the **modifications** which arise are **almost endless,** and these are closely associated with other branches of farm husbandry.

CHAPTER XXXI.

IT has been shown that the food of animals necessarily influences the excrement produced, which in its turn causes a difference in the character of the farm-yard manure. In consequence of this, the fermentation of manure, possessing great variation in character, becomes somewhat difficult of control. The ultimate value of the farm-yard manure greatly depends upon **the fermentation** being **judiciously regulated,** making it, in fact, a means for improving its character, instead of decreasing the quantity of the fertilising matter it contains. It is a fact well known to every farmer, that the manure from the

stables is disposed to become **hot** very quickly, whilst that from the cow-stables is known as a **cold** manure. This difference arises from the former containing much nitrogenous matter, which quickly causes a fermentation of the manure to be commenced. On the other hand the manure from the cow-stalls has a considerably smaller proportion of nitrogen, and it ferments very slowly. Other instances might be given of these variations in character, but the general result is that different parts of the farm-yard have manures differing in composition. Thus, whilst in **some parts** the manure is **fermenting too rapidly,** and needs moisture to make its fermentation safe, **other portions** are already **too moist** and cool for the proper changes to take place in the same time. Hence the great importance of having these various kinds of manure **spread equally** so that they may become **properly mixed.** In this way the general mass or heap can be **similarly treated,** and one common course of management adopted for the whole. If fermentation needs quickening, the manure can be turned and air admitted, or, if it needs more water, it can be applied. A tolerably uniform heap of manure having been secured, it becomes comparatively easy to determine what should be done. There is, however, another advantage gained by such intermixture, for we not only secure a safe fermentation, but the general preparation of the manure is also quickened. The slower portions advantageously *check the* more rapid, whilst those are in return

rendered more active. The general issue is, that a great uniformity, a well-regulated fermentation, and an early preparation for use upon the land, are secured.

There are, however, other important practical advantages which result from our recognising the connection existing between the food consumed and the excrement produced. Of these the superior quality and value of the manure of animals fed upon food which contains rich nitrogenous matter will immediately occur to the mind. The successful use of artificial food and corn as a means for producing meat, is largely based upon this fact. So much so indeed is this recognised, that the returns arising from the outlay are not simply looked for from the meat produced, but also from the increased value of the manure obtained. In some cases this has been estimated at figures which are a matter of surprise to practical men, and yet these estimates are based upon the market value of the materials actually present in the manure. The investigations which have been carried out by Messrs. Lawes and Gilbert place facts before us of immense importance, and they are known to have been carried out with such care and skill as to place agriculturists under the very deepest obligations to them. It has been shown that it is possible to obtain from a ton of each of the following descriptions of food a manure enriched by these foods with fertilising substances having a total market value equal to the amounts stated in each case:—

	Per ton used.		
Cotton seed cake (decorticated)	£6	10	0
Rape cake	4	18	6
Linseed cake	4	12	6
Malt dust	4	5	6
Cotton seed cake (un-decorticated)	3	18	6
Beans	3	14	0
Linseed	3	13	0
Peas	3	2	6
Bran and Pollards	2	18	0
Clover hay	2	5	6
Oats	1	15	0
Wheat	1	13	0
Malt	1	11	6
Indian meal	1	11	0
Meadow hay	1	10	6
Barley	1	10	0
Locust beans	1	2	6
Bean straw	1	0	6
Pea straw	0	18	9
Oat straw	0	13	6
Wheat straw	0	12	6
Barley straw	0	10	9
Potatoes	0	7	0
Mangel wurzel	0	5	3
Swedish turnips	0	4	3
Turnips and carrots	0	4	0

These results represent an amount of labour and skill of which few can form any adequate conception, and they give us information of enormous value, for which we cannot feel too grateful. It will be evident that these figures indicate the power to enrich farm-yard manure to a very great degree, and they become important data in calculating the advantages which may arise from the use of saleable farm produce and purchased food. They

also show **results which have been attained,** and consequently **may be again** secured under **similar** management, and with **similar** animals.

These facts also tend to prove the immense importance of care and judgment being shown in the management of farm-yard manure, especially that which has been enriched by the use of expensive food. The realisation of **the best results** is largely dependent upon **an avoidance of all waste,** and on the **proper fermentation of the manure** before it is applied to the land. Apart from the care of this manure whilst in the homestead, its preservation whilst in heap awaiting use, demands equal attention. Any waste by drainage into the ground on which it rests should be prevented by securing an impervious bottom on which it may be placed, and by passing the carts over the heap when it has to be kept without much advance of fermentation, and of course surrounding it for a moderate height by earthy matter. The plan introduced by Mr. Clement Cadle, of **mixing some kainit with the farm-yard manure** as it is being made into heap, promises to become widely adopted, and to be of immense advantage. If it be scattered over each layer in the heap—say at the rate of half-a-cwt. for each ton of manure—it will have a tendency to fix any ammonia that may be formed in a volatile condition, and will itself become changed into one of our most valuable potash salts. It is one of the best means of obtaining **a cheap supply of potash** in an effective condition, and is well worthy of

general adoption. It may be added that this German potash salt kainit, consists largely of sulphate of potash—that is, sulphuric acid and potash; and, in the presence of fermenting farm-yard manure, it is largely changed into nitrate and carbonate of potash, whilst its sulphuric acid fixes any volatile ammonia with which it comes in contact. The use of kainit in this manner will be found an additional means for preserving and enriching farm-yard manure.

CHAPTER XXXII.

THERE are many cases arising on a farm where the **manure** differs from farm-yard manure in **not having any straw** or other litter intermixed with it. On many farms—for instance sheep-farms—this mode of manuring becomes the most important. In these cases the excrement of the animals is **deposited upon the land,** without any interference on the part of those in care of the stock. Even in these cases it is quite possible for an important control to be exercised. In this group of fertilisers we have all manures produced upon the farm by the consumption of growing crops, and in it are therefore comprised such as result from grazing and folding. In the grazing of horses and cattle little is done except having the manure dropped upon the land knocked about, so as to secure its more perfect distribution. Where this is neglected we have a **rank**

and vigorous **growth** of grass or other herbage, which stock do not relish, and which they avoid as long as possible. **Frosty weather** very generally corrects this rankness, and the herbage becomes "**sweetened**" by the severe cold, so that the stock are then more willing to eat it. By means of the system of **folding** the land,—that is, keeping the sheep upon the land within hurdles, and on a limited space,—the feeding is concentrated within the limits assigned; consequently any food is more rapidly fed off by stock, and the manure is more regularly distributed over the surface. This cannot be done as a rule with any other stock than **sheep,** and even with sheep there is a very great difference observable between our several breeds. There are cases occasionally met with in which pigs and young cattle undergo the same treatment.

The system of **folding sheep** has been carried out very extensively for assisting the proper consumption of **root-crops.** In this way it has encouraged a more **perfect consumption of the food** which has been grown, and as less has been wasted in the feeding of the crop, more has been used as food. Under this system of folding one great advantage, amongst many others, has been gained, for a tolerably **equal distribution of the manure** has been secured. Unless this or some similar system be adopted, the sheep will resort to their **favourite lairs** or resting-places, and these spots will receive **too much** manure, whilst **other parts** of the same field will be **without any.** The

large proportion of nitrogenous matter thus given to the favourite spots generally results in a very vigorous growth of the straw, often producing such an excessive quantity that the corn-crop falls before it comes to maturity. On other parts of the same field the absence of manure is especially marked, for the growth is slow, and the crop is consequently backward, and a partial failure. Both of these objections are removed by an equal distribution, and in this way a more equal and a more productive yield of corn is obtained. The favourable results extend beyond the quantity grown, and are even more observable in the quality of the corn produced.

It is only right that, in restricting sheep from resorting to their favourite lairs, we should carefully notice why they give such a decided preference to these spots. Such preference is generally exercised by reason of some instinctive guidance, and it is but prudent to be assured that in counteracting this natural desire we provide an adequate substitute. Two conditions generally influence the preference thus shown by sheep: shelter from cold winds, and dryness of soil. The former can be readily supplied by the use of light hurdles covered by thin boarding, or by the employment of wattled flakes, both of which can be shifted as easily as ordinary hurdles. If it should be intended to have a more permanent fold, a double row of hurdles stuffed with straw gives even more perfect shelter, but for all ordinary purposes either of the former *will answer* every requirement. The general use of

such shelter-giving hurdles proves to be extremely remunerative; for whether the flock may be for breeding or for feeding purposes, the importance of having one or two sides of each fold sheltered from the cold and searching winds will soon become manifest. The dryness of the soil is not equally under our control, for although the drainage of the land will do much to improve it in this respect, much more than this is required, in many cases, before the land becomes sound for folding. On moist soils the folds will generally be made larger than usual, so as to prevent the soil being too much trodden. Just in proportion as the proportion of sand decreases and as the clay increases, so does the density of the soil decrease; and this results in the soil being rendered more retentive of moisture, and more easily rendered muddy. If, for the purpose of securing an equal distribution of the manure, we prevent a flock selecting its own lair at night, it is alike our duty and our interest to provide artificially that which they seek to secure naturally. Whether it be the cold piercing wind which penetrates the fleece and chills the body of the animal, or whether it be the moisture arising from lying on the wet soil, in each case the warmth of the animal is drawn upon to rectify, in some degree, the mischief, and that causes a waste of food, even if it does not establish a diseased condition of the body.

The practice of folding not only influences the distribution of the manure, but in some cases it increases the quantity produced. This is notably

the case in feeding clovers and other growing crops. As each portion of the field is successively folded off and then cleared of stock, an immediate and an uninterrupted growth takes place; whereas, if the sheep have a freedom to run over the entire field, they continue eating the youngest growths in preference to that which is older, and which constitutes by far the greater portion of the feed. It is needless to say that this mode of eating the crop must prejudice the growth during the time the sheep are on the land. In one case the growth is checked for four or five days; in the other case probably for four or five weeks, or as long as the crop in the field is being eaten. In consequence of a smaller growth of herbage, a smaller quantity of manure must be produced. This deficiency of growth is necessarily accompanied by a decreased absorption of fertilising matter from the atmosphere, and a diminished production of very valuable organic matter in the soil. The growth of the clover under favourable circumstances is accompanied by an increase of fertilising matter added to our soils, and a prompt feeding (or cutting) of the crop gives so much more time for a luxuriant growth. The several prejudicial influences resulting from the ordinary mode of feeding our crops of clover have also an important bearing upon the quantity of stock which the land is capable of maintaining. The higher the productive power of the land, the greater will be the difference in the number of stock which can be carried under the two *systems*. The quantity of manure produced will also

show a wide range of difference, for under the one system the manure obtained will in some cases be about double the value of that produced under a less judicious course of procedure.

CHAPTER XXXIII.

It is a well-known fact that all herbage plants become more and **more nutritious** as they advance towards **full maturity.** It follows as a natural consequence that when a growing crop is allowed to perfect its growth, not only is a larger growth produced, but the yield possesses a more valuable character. This can only be satisfactorily attained by **preventing** all **interruption in the growth,** for if, whilst the crop is making the required advance, portions are eaten off long before they have arrived at their best condition, and other parts are trodden down and damaged, the entire growth is largely interfered with. Hence some have even gone so far in economising the food as to keep the field clear until the growth is nearly perfected, and then the crop is cut and fed off with the greatest regularity. The production of **manure** is greatly **increased** by such an arrangement, and the **quality** of the manure is **improved,** whilst at the same time the land has received a corresponding increase in the rich organic matters produced by the roots of a well-grown clover or fodder crop.

Another mode of manuring lands is largely carried out in the neighbourhood of our downs, wolds, and

common-lands. During the day the flocks graze upon the uncultivated grounds, and occasionally on other lands, and return at night to be folded upon land intended for corn, or even for roots. In some cases they are brought back to consume vetches, mustard, roots, etc.; but in each and every case the tillage-land gains manure at the cost of the rougher grazing-land. The shepherd takes care to move the flock about within the fold some short time before the sheep go off for the day, the object being to secure a deposit of the manure within the fold where it is wanted.

It may be desirable to glance for a moment at the general character of the manures thus added to the land. It will differ in composition according to the character of the food upon which the sheep or other animals may have been feeding. In the case of clover and similar highly nutritious crops, the manure will be far more enriching to the land than when the sheep have fed on poor and weak herbage of low quality. But we must not imagine that we shall always have such inferior results, for much of the grazing in the downs and wolds gives the sheep a good quality and sweet pasturage, even though it may be short. It is the residue of such food, after it has yielded to the body that portion which is suitable and necessary, which passes away from the animal as manure. Hence the richer food gives manure more highly nitrogenised, whilst the phosphates have very generally been abstracted for the requirements of the animal body.

The same principle holds good in those cases where sheep receive **artificial food,** such as corn and cake, for here also the richer foods yield **a richer manure.** The money value of the manure produced from various articles of food has been given (on page 154), and it is based upon very high authority. We have in fact an opportunity of enriching land to a very great extent in this way, especially when such food is consumed upon dry land having a good holding character, which will prevent a loss of the fertilising matter so added.

There is another form in which we have to deal with animal manures without straw, and this is met with **when stock are kept** upon open sparred floors **without bedding.** Some dry material, such as peat charcoal, burnt clay, peat ashes, or the ashes of weeds, is generally mixed with such manure to facilitate its distribution over the land.

It is necessary before concluding these remarks upon farm-manures to refer to **two** systems under which farm-yard manure is made, viz. the **box or pit system,** and the **stall system:** under the former system the excrements and the litter are so kept within a **pit** that **no separation** of the **solid** and **liquid** portions of the manure takes place. An excavation is usually made from two to four feet below the level of the ground, and a water-tight bottom and sides are formed by masonry or otherwise. Litter is freely supplied, and a heap of manure gradually accumulates on which the animal rests with comfort, until at length it rises to the level of the ground, and

the bullock walks out ready for the butcher. Here then we have any separation of the manure prevented, and when the accumulation is removed it is generally found in excellent condition. Under the stall system the solid and the liquid portions soon separate, and both demand special care to prevent loss arising during fermentation and storage. One objection which has been advanced against the box system is the larger quantity of litter which is needed, but on some farms this ceases to be objectionable. The character of the manure made under the box system is very generally admitted to be of superior quality for the same quantity of food used.

The liquid manure largely separates under other systems of stall or shed feeding, and reference has already been made to the advantages of bringing back the liquid manure to the heap when fermentation is progressing. The advantages of a moderate supply of moisture in the manure heap are so great that it must ever be remembered as an essential of good management. It very often happens that there is more liquid manure than can be advantageously used upon the solid manure. Hence some other means for employing the liquid manure has often to be found. It should never be allowed to run to waste, but distributed over any ground within easy reach. The use of liquid manure is in many respects exceptional in its character, and will be most satisfactorily dealt with when irrigation work comes under notice. It may, however, be mentioned in passing that it has been successfully used upon

almost every variety of soil and for all kinds of crops. The necessity for its dilution must be remembered, especially if it be used during the time of active plant-growth. The valuable constituents present in liquid manure **rarely pay for carriage,** and hence a gravitation supply to the land is generally accepted as a necessity of the case. Nor are we without evidence that the action of any given quality of liquid manure may be very generally **increased by dilution**; but in the practical application of this experience we have to consider in the first place **the cost of distribution,** and then increase the dilution in a manner somewhat proportionate to the freedom with which it passes through the soil.

This addition of water effects a very desirable **mechanical** change in the liquid manure, but we must not overlook the fact of **chemical** changes taking place in it, whereby ammoniacal salts are formed. The early experience of its use tended rather in favour of the liquid manure being kept in tanks until after this decomposition had been far advanced and ammonia had been formed, but the great majority of these trials took place upon light soils. More recent experience favours the use of liquid manure, without keeping it in store to undergo such a decomposition. There is some ground to believe that just in proportion as soils possess those absorptive powers which guard against loss of fertilising matter, so such soils may be safely entrusted with liquid manure without any previous decomposition being waited for.

CHAPTER XXXIV.

BESIDES those farm manures which are obtained by the consumption of crops by stock, and by the careful use of the excrement and litter, there is another group of manures obtained by using certain crops as direct fertilisers of the land. This is a means of enriching and improving the soil of this country more powerfully and to a very much greater extent than is commonly accepted by the great majority of farmers. The term **Green Manuring,** has been commonly applied to the system of **growing a crop** for the express purpose of **ploughing it into the land** as a manure before it has undergone decomposition, the green colour being generally retained by this vegetable matter up to the time of its being buried. If a crop which has grown upon a field be returned to it, it may at first appear very much like giving back to the land that which was really its own material. But there are distinct reasons, which explain the advantages that have been seen to arise from the practice.

In the first place there is the advantage secured of plant-food being drawn from all parts of the soil by some hardy crop, and often it has been gathered from a depth in the soil to which our more delicate cultivated crops could not penetrate. Thus **plant-food is rendered serviceable** which was previously out *of reach.* Then, again, the plant-food is presented

to the new crop **in a more complete form,** by reason of its having been taken up into the previous growth of a plant. It may not be a sufficiently complete food to meet the full requirements of new crop, but at any rate very material progress has been made in that direction, and so much less remains to be done. The further advantage is gained, of such plant-food being presented **in a gradually progressive manner.** Just as the green manure becomes more and more decomposed in the soil, so will the inorganic matter it contains be released from imprisonment, and be free for again entering into vegetable growth. Thus, although there may be no actual addition of inorganic matter to the soil, there are very manifest advantages gained. It is, however, more than probable that, during the decay of this green manure in the soil, the solvent powers of the carbonic and organic acids formed, results in a direct increase of the quantity of available plant-food.

The greatest advantages obtained by the use of green manures must be acknowledged as resulting from **the addition of organic matter** to the soil. The chief portion of the organic matter so added may be traced as coming **from the atmosphere** above the land, rather than from the soil itself. In this respect it **contrasts** in a very striking manner **with the inorganic matters,** which, being taken from the soil, are again added to the soil. Here we have a distinct addition of new matter, capable of exerting very marked influences upon the fertility of the soil. In this way the field is enriched by an

increase of valuable nitrogenous and carbonaceous matter.

Two very opposite **classes of soil** are **improved** by this system. The more general practice is observed upon **thin poor soils,** frequently sandy, but of very inferior fertilising power. In these cases by the growth of hardy crops, such as mustard, buck-wheat, and rape, or in fact any other crop suited to the district, as the lupin and borage, a largely increased supply of organic matter is introduced into the soil. The advantages are quickly manifest, for the soil is thereby enabled to **hold larger supplies of moisture,** it can take in more gaseous matter and moisture from the atmosphere. Such soils may thus be progressively **enriched,** and with the aid of some judiciously selected manure, they may become valuable tillage land. However great the advantages gained by this introduction of organic matter it still has its limits of usefulness, for it must be remembered that **no addition of inorganic matter** is thus secured. If, therefore, the soil should be deficient in some necessary constituent of plant-food—phosphoric acid for instance—however long the green manuring were continued **this defect would not be remedied.** Hence the importance of being informed upon the composition of the soil, for this would enable the work to be judiciously assisted and rendered more certain of success.

The second description of soils on which the system can be successfully practised, are our **heavy clays.** In these cases the introduction of organic

matter in the form of green manures exerts a very marked influence. Much of the extreme difficulty of cultivation is removed, by the soil being rendered less sticky and adhesive, by this intermixture of vegetable matter. It is a matter of common observation that when such land has been laid down in grass for several years, the roots penetrate through the upper soil and divide it very completely, in fact changing it into the appearance of a garden soil. The more fully such clay soils are broken up and separated by particles of vegetable matter, the more easy will the labour of working such a soil become, and the more fully will its fertility be promoted.

The growth of clover root is one of the most general means of showing how greatly soils are improved by the presence of vegetable matter. It matters not whether it be upon light lands or heavy soils, or those of intermediate character, in each and every case we find the condition and the fertilising powers of such soils improved and increased. It is a very important lesson which may thus be learned, and it should certainly lead us to value more highly the beneficial results arising from green manuring. In many other ways we obtain indirect evidence of this advance in fertility. It is not merely a difference which the eye readily detects in the appearance of the soil, but it is also shown by an increase in the productiveness of the land.

There are certain points of character which should be possessed by any crops used for the production of green manures. Such a crop should have

powers of quick growth, in order that the land may not be detained about its own improvement longer than is absolutely necessary. A **deep-rooted** plant is also desirable, as fertilising matter can thus be gathered and drawn up from a depth below the ordinary level to which cultivated crops reach. It is also desirable that the plant selected should be hardy and **vigorous in its habits of growth,** for, having pioneer duty to perform, these qualities will be valuable. Large leaves and a large extent of leaf surface are considered desirable, by reason of the additional opportunities for drawing upon the atmosphere for any fertilising matters it may contain. The character of the organic matter produced will also vary, but those **crops which yield** the largest quantity of **nitrogenous matters** will be the more valuable; hence the general favour which is given to the clover plant as soon as the land is sufficiently improved to enable its growth to be successfully carried out.

CHAPTER XXXV.

THE clover crop is in some respects **exceptional** from other crops grown for the purposes of **green manuring,** because it is allowed to stand for a longer period before it is ploughed in. In the meantime it is not only making a **growth above ground,** but also **beneath the surface.** In *noticing* the cultivation of the clover crop, we are

forcibly reminded in our system of management of the fact, that the growth beneath the surface is largely proportioned to the growth above the surface. Hence it follows that if we desire to secure a large growth of root we must encourage the growth of the general crop by letting it stand for mowing. If the growth on the surface should be constantly checked by sheep feeding upon the crop, the extension of the root suffers proportionate delay. It was for a long time a matter of surprise that farmers should assert, and with much confidence, that a double cutting of the clover was frequently a better preparation for the growth of a crop of wheat, than a single cutting of the crop, followed by sheep feeding the second growth upon the land. It was argued by some that the second growth being consumed upon the land, and much of it returned to the soil in the form of manure, must of necessity leave the land in better condition for wheat. Facts were as stubborn as usual, but the analysis of the clover root ultimately showed that it was rich in nitrogenous matter, and that the land very often gained more by encouraging its growth than by the manure added to the surface.

The mechanical influence of green manures is most powerfully illustrated by this growth of clover root, exceptional though it be. In the whole range of agricultural experience it would be difficult to find more opposite influences arising from one agency. It is well known to every farmer that the clover root gives firmness to light soils, which without its aid

could not possibly grow wheat, and upon heavy clay soils it gives an open character which encourages the growth of the root of the wheat plant, and secures, in a great measure, its ultimate success. To the attainment of these two somewhat opposite results the use of green manures should be directed.

Many of our crops incidentally furnish supplies of green manure to the land, as in the case of "roots" grown for consumption in the homestead, whilst the tops are left on the ground. The same thing is observable in growing the potato crop, when the haulm is left on the surface. These are only partial applications of the system, and, indeed, we find various similar modifications. There is a reluctance to bury as manure any crop, or even a portion of a crop, which can be used as food. It is a somewhat prevailing idea that sheep feeding upon vegetable matter render it more useful to the land by allowing the sheep to convert it into manure. In forming such an opinion, the facts are entirely overlooked that the sheep makes use of much of the vegetable matter for its own benefit, taking from it both organic and mineral ingredients, and using these in its own body. It may be said that this is a profitable use of the vegetable matter, and this may be perfectly true; but it must not be forgotten that the soil has not received the same matter in both cases, still less has it become improved in some mysterious manner by passing through the sheep. Further than this, the mechanical influence of such vegetable matter has been altered. It is true

that in some cases, as on sandy soils, this has some compensating advantages, but the rigidity of structure which is especially useful upon heavy clay soils is certainly lost.

Two forms of vegetable matter are largely used in this country as **green manures** which are **not grown upon the land** into which they are ploughed, neither are they grown for this special use, as in other cases. **Sea-weed** and **fern** or bracken are the substances referred to. Their use is of necessity limited to those neighbourhoods in which they are easily obtained, and with only a **short carriage.** On some of our coasts the sea-weed is very largely employed, and generally with great success. It is used in large quantities, and has been tried in contrast with good farm-yard manure. Many of these **manure experiments** are carried out under conditions which are so indefinite that they must be **received with caution** and reserve. One field trial may, however, be mentioned, in which about eighty tons per acre of fresh **sea-weed** was applied and immediately ploughed into the land. On another portion of the same field about thirty tons per acre of good **farm-yard manure** and three bushels of salt per acre were applied, but the resulting crops of wheat were largely **in favour of the sea-weed.** In fact, on many parts of the coast, and especially in some of the small islands around our coast, farmers depend very largely upon this source of manure.

The fern or bracken has also been **used with**

success, and in neighbourhoods where it can be obtained at a small cost it will be found valuable for use as a green manure. It should be cut and used whilst still green, as it is more effective in this condition than when it has become dry. In some cases the fern is thrown into a heap and moistened with water, so as to cause it to ferment and become rotten. This will probably hasten its decomposition when added to the soil. One interesting experiment may be mentioned here as illustrating the use of ferns. A field naturally barren and much exhausted came into the owner's possession. In an adjoining plantation there was an abundance of fern growing, and this was cut in the middle of June, and placed in a heap for a few days to encourage its decomposition before being spread between ridges for covering up with soil. Another portion of the same field was manured with dung from the fold yard, and the field was sown with turnips. The early growth of the turnip crop was most rapid where the fern was used, and during the later growth of the crop this portion was distinctly marked by its stronger growth. This illustration of its use may serve to show that in the ferns we have a very useful source of manure, which is too frequently neglected.

The use of green manures is likely to extend, and especially with the object of improving the condition of many of our poor soils. It is very rarely that the legitimate use of green manures has been carried out with sufficient perseverance, and still more

rarely has the system been assisted by judiciously selected manures. On some of our poor clay soils this is a system which promises many advantages, for any cheap and inexpensive means whereby draining such soils can be so supplemented by the introduction of vegetable matter into and amongst the particles of the soil, as to change or modify the ordinary adhesive character of these soils, is calculated to be a valuable help in their improvement.

CHAPTER XXXVI.

IN the use of lime the farmer has a very powerful promoter of fertility in the soil. It forms part of a series of natural manures which are exceedingly useful in encouraging the growth of farm crops. A very remarkable change is observable in its use during the last 30 or 40 years, for it is far less freely used now than it was then. It may be readily admitted that at that time its use was somewhat too free, or not sufficiently balanced by other manures, but it is more than probable that the practice of farmers has run too much to the opposite extreme. Cheaper and less effective manures have been adopted, but with distinct disadvantage to the production of corn of high feeding character.

There are two very distinct conditions in which lime is used upon the land. We have it in a very vigorous and quick condition, by reason of its having been

burnt, and we also use it just as it has been raised from the rocks or beds in which it exists naturally. It will be desirable in the first place to notice those forms of lime which have been roasted or burnt. These are familiar to us, as the **quick** lime, the **burnt** lime, the **caustic** lime, used both by farmers and builders, and these are chiefly produced from **limestone rocks**, or from **chalk,** by what is commonly known as **burning in the kiln.** There are various arrangements for carrying out this burning which cannot be referred to here, but all arrive at one common result, which should be clearly understood.

In limestone and chalk we find lime **united with** another body, known to us as **carbonic acid.** There is a very strong attachment existing between them. They are therefore **difficult to separate,** and when they have been separated, they **do their best to be united again.** This fact will greatly assist us, in clearly understanding much that is peculiar in lime. To separate these two bodies fire has to be employed, and as the limestone and chalk cannot burn without some fuel being used, it is necessary to employ coal and similar matters to roast the limestone and chalk. This is usually done in kilns, the unburnt lime and coal being added at the top, and the burnt lime being drawn from the bottom. The change which has thus been carried out is the **separation of the carbonic acid from the lime.** The carbonic acid is driven off from the top of the kiln, and becomes dispersed *in* the atmosphere. We do not see it depart, because

it is as colourless as the air we breathe, but we know by the altered appearance and behaviour of the lime that the separation has been made.

The lime is lighter after it has been burnt, because all the water and all the carbonic acid have been driven away from it. Its **desire for water** is so **great,** that when a little water is added to the burnt lime, it is so rapidly taken into combination with the lime that **great heat** is manifested. Thus, when a mason slakes the burnt lime by adding water, it cracks and becomes very hot, and finally it becomes as finely divided as a powder. Whatever may be the use to which **the builder** has to apply it, we see that **as soon as** he has added sufficient water to bring the lime into this finely divided condition, he then **covers it up** with sand, or some other material, to protect it as much as possible from further change. In this state it is known as **slaked lime** or hydrate of calcium.

The builder's experience has shown that if he desires to secure **good mortar,** he must **protect his slaked lime** from the atmosphere. If he does not do so, some carbonic acid from the atmosphere unites with the lime and forms a carbonate of lime, which does not make a sound and strong mortar. **The carbonic acid** which thus unites with the lime, will be remembered as the gas which was **driven off in the kiln,** and thus it will be seen that it was not only very unwilling to leave the lime, but **very anxious to get back** to it again. Thus, when burnt lime is exposed to the atmosphere the advan-

tages of burning are gradually lost. **The mason** knows this, and **takes care of his lime,** or else his work would be condemned, because he had made **bad mortar**; but it will be seen that **the farmer,** who is **careless** about the protection of his burnt lime, is quite as great a **loser** as the mason would have been if he had neglected his lime.

Here we have another instance of "**out of sight, out of mind.**" **The mason** would soon **see the result** of neglect, but **the farmer does not see** the waste he has made, and perhaps naturally hopes it will all come right in the end. **If he could see** the loss he suffers of a valuable and expensive manure, **he would soon adopt a good system.** We should no longer see the lime drawn out and placed on small heaps on the land, and there left to be attacked by the carbonic acid in the atmosphere. **Some farmers** know the value of lime, and **avoid such waste.** They have a supply of water sent after the lime-cart, and as soon as the heap of burnt lime is made, it is slaked,—just as a mason would do it,—and then covered with some earth. In this way its safety is fairly secured until it can be **spread upon the land** and harrowed in. There is a very good reason for harrowing in the lime as soon as it is spread. If it were allowed to remain on the surface it would soon be turned into carbonate again, by the carbonic acid in the air; hence it is **immediately harrowed into the soil,** and the lime exerts its powers usefully. The first reason for harrowing in *the lime is to* set it to work at once without waste, but

there is another reason. We want the lime **covered,** but we must **not cover it in deeply.** The **harrow** sends it into the ground deep enough, but **not too deep.** If some one should **plough** it into the land it would be **buried too deep,** for at whatever depth it happens to be buried the lime manages to **work itself down** to a lower level. If the lime starts at a low level, it is less useful to the soil, and is much sooner too deep to be of full service to the growing crop. Thus the lime is buried in the soil as soon as it is spread, but still kept in the upper soil.

When lime used to be applied more freely than it is now, and less care was taken of it, it was not uncommon for a large quantity of **lime** to sink **beneath the ploughed soil** and work its way into the plough pan, forming **a lime pan** or calcareous pan. These pans often became great **impediments to cultivation,** especially when this work could only be done by horses and bullocks. With the steam-plough and steam cultivators of the present time, we should have no difficulty in breaking up any such obstacles, and securing a clear passage for air and water. But **prevention** is very much **better than cure,** and the fact that we can correct the difficulty must not encourage a wasteful and undesirable practice.

CHAPTER XXXVII.

THE two conditions in which lime is used upon the land—namely, after burning, and also in its natural condition,—enable us to select it in that form which will be most suitable for any particular soil. It is, however, very desirable that a clear knowledge should be secured of the action of lime in each of these conditions, so that there may be no doubt as to the form which will best meet the requirements which have to be dealt with. The burnt lime or quick-lime shall receive attention in the first place. The action which this body exerts upon the organic matter of the soil is one which is full of importance and interest. It will be remembered that lime in this caustic form is very powerful, and that it seeks to effect a reunion with the carbonic acid, which was forcibly separated from it by the burning in the kiln, until it secures a full supply and has again taken the form of carbonate. When caustic lime comes in contact with organic matter in the soil its decomposition is rendered more rapid under the influence of the lime. As any organic acids are formed, so these combine with the lime, the structural character of the organic matter soon disappears, and ultimately the lime loses its caustic character, and chemical compounds of lime are formed. The first result of this action of caustic lime is to neutralise any acid bodies existing in the soil, and which

may have given the soil a sour character. The second result is a decrease in the quantity of the organic matter in the soil.

It needs not the evidence of a chemical examination of the soil to determine whether or not the soil contains materials which render it "sour," for it is known alike to man and beast. The harsh, tough, wiry growth is seen by the farmer, and his stock avoid eating it if more nutritious pasture is to be found. The mower finds that his scythe quickly loses its sharp edge, and the stock long for a "sweeter" pasture. This common use of the term "sweetness" as contrasted with "sourness," shows a correct knowledge which has never been taught by chemistry. The term "sweetness" may not be exactly accurate, but as representing the opposite of "sourness" it is suitable and appropriate. It certainly indicates a more nutritious herbage, and one more relished by stock of all kinds. The closeness with which it is eaten, when there may be a long growth on other parts of the field, gives proof of a preference which is known to every farmer; whilst the careful observer will often notice that the herbage produced under the action of lime, consists of an entirely different class of grasses, and that a race of more valuable plants have thus been enabled to establish themselves upon the land. This difference in the herbage, is one of the evidences of the improved fertility of the soil.

We must not close our eyes to the fact that there is a decrease in the organic matter of the soil.

In those cases in which there is an abundant supply of organic matter in the soil this action is not objectionable, and in some cases it is really desirable. This is especially observable when more healthy conditions of growth are thus established in the soil. There are, however, some soils, especially such as have a large percentage of sand—sands and sandy loams—which cannot allow the organic matter to be materially reduced without a considerable sacrifice of productive power. In such soils much of the power of raising water from the lower layer of the soil, much of the power of absorbing moisture and gases from the air, as well as much of the power of holding moisture and manure, are all influenced by the organic matter in the soil. On soils of this character—sands and sandy loams—the use of lime in a caustic condition is very seldom desirable. Even upon stronger soils than these, the use of caustic lime renders a supplemental supply of organic matter very generally desirable. It is just one of those occasions, in which the use of burnt lime by reason of its violent action upon the organic matter, necessitates the addition of such matter to the soil by means of manure or by plant-growth.

We may for a moment stay to notice what would have been the difference in the action upon this organic matter, if we had used some milder form of lime instead of the caustic lime, say chalk for instance. In the first place, the action would have been slower, the acid character of the soil would

have been gradually corrected, and very much less of the organic matter would have been used up. The urgent necessity for restoring the organic matter of the soil would not have arisen. From this we may learn why it is some skilful farmers avoid the use of burnt or quick-lime. They see that something not quite so quick gives better results, and hence they select some form of lime in which this substance exists as a carbonate. Lime in each of these two conditions—burnt and in its natural state—has its proper duties to discharge; but it becomes a matter of duty to apply it to the land in that state, in which it will be most beneficial and profitable.

There is another duty which lime has to discharge, and this is one in which it is necessary to use it in the caustic condition as quick-lime. It has been necessary in some of the earlier chapters to refer to the "dormant" matter in soils, and to explain the necessity for changing it into an active condition. For this work quick-lime is one of our most powerful agents, and by its aid alkaline matter, such as potash and soda, is released from its associations, and brought into a condition useful for vegetation. In the minute rocky particles of our soils we often find some of the silicates of potash and soda; when these are brought under the influence of caustic lime, the potash and soda are partially displaced from their combinations with the silica, and the lime takes their place. The result is that these valuable fertilising substances are set free from a combination,

which would have resisted the ordinary decomposing forces of the soil and of plant life, and are by the help of the caustic lime rendered useful for vegetation.

Neither must we overlook the fact that just in proportion as lime promotes the decomposition of the organic matter of the soil, so does it thereby liberate the inorganic matter locked up in it. All such organic matter required for the purposes of its own growth, those various inorganic matters which were necessary for strengthening its own structure, and for enabling it to perform its own duties as a perfect organism. Its duties being now ended, decomposition sets in, and the constituent materials which had served all the purposes of life are now set free, to be built up into new forms of life, and to enter upon new conditions of usefulness.

CHAPTER XXXVIII.

ANOTHER duty which **caustic lime** discharges in the soil is assisting the formation of a very important class of bodies known as **the double silicates.** These substances have been already referred to, and it has been explained that the **silicate of alumina,** by some means or other, is induced to **take in another associate,** such as ammonia, or potash, or lime, or soda. Pure clay may be regarded as silicate of alumina, and in agricultural clay it becomes mixed with a variety of other substances, necessary to give

it powers of fertility. Under these circumstances it is very common for a small percentage of the clay — silicate of alumina — to take a somewhat modified form, and become converted into these double silicates. The various means by which these substances are formed are by no means clearly known, but there is good reason to believe that clays increase in fertility with any increase in the percentage of these double silicates. As more is discovered as to the conditions which favour their production, we shall probably find that they are even more valuable assistants, than they are considered to be at the present time.

These double silicates are as follows :—

Silicate of alumina and ammonia.
Silicate of alumina and potash.
Silicate of alumina and lime.
Silicate of alumina and soda.

It will, therefore, be evident that we have to secure the introduction of a new partner in the firm. The great difficulty is to secure a commencement of the series; this being accomplished, the change from the one to the other is a matter of choice, according to a known order of succession. The double soda silicate is the lowest in the series, and soda is the lowest favourite, for if either lime, or potash, or ammonia is presented in proper form, the soda may "go about its business," and one of these higher favourites takes the vacant place. In the case of the double lime silicate just the same change occurs, if potash or ammonia comes forward in

proper form—the lime being released and **a higher favourite** joining in the new compound. But when we come to the double potash silicate, only one substance—the ammonia—can turn out the potash. When it has reached the highest stage it is in the most valuable condition for promoting the growth of vegetation.

The use of **caustic lime** upon clay has the effect of favouring the production of **the double lime silicate,** and the old-fashioned system of slaking caustic lime by the use of water in which salt has been dissolved, will probably encourage the work. It is, however, clearly desirable that further progress should be made, in obtaining a fuller knowledge of the means whereby these double silicates can be formed in the soil. It may be that **a cheap supply** may ere long be available, for adding to sands and sandy loams **as an artificial manure.** We cannot adequately estimate the value of such knowledge, nor realise the difference it would make in the value of our poor clays or poor sands.

We have **another work** to notice in the soil resulting from the use of lime, which is scarcely inferior in importance to the foregoing, namely, **the production of nitrate of potash.** This is a substance which is **not purchased** for use as an artificial manure, simply because its employment for the manufacture of gunpowder gives it an **exceptional value.** The great value of this substance as a manure is still **very well known.** In by-gone years, when railways were unknown, and wood was consequently

burnt in nearly all our farm-houses, the value of the wood ashes was known throughout the country. These wood ashes contained a considerable quantity of potash, and the desire for an abundant supply of this substance has long been the desire of farmers. The means for producing **artificially** a cheap supply of nitrate of potash was introduced into France by Monsieur Thouvenel in 1776, at a time when there was an intense desire entertained in that country to become quite independent of imported supplies of this important constituent of gunpowder. The difficulty was overcome, and enormous quantities were produced by a system known as **Nitre Beds** or Saltpetre plantations. It may be a matter of interest to some to be informed that in 1741 a patent was granted in this country to Thomas Harris for the production of "saltpetre or nitre" upon a plan very similar to that which was subsequently introduced into France by Monsieur Thouvenel, and for which he gained the Government prize. In fact, as early as 1630 David Ramseye obtained Letters-Patent in England "to multiplie and make saltpeter in an open fielde in fower acres of ground sufficient to serve all our dominions." Other patents were granted for a similar purpose in 1632 and 1691, showing that a considerable amount of attention had been given to the production of nitrate of potash. But it must be added that the arts of war appear to have stimulated its production, much more than the fertilisation of the soil.

The principle upon which these nitre beds were

formed is a matter of interest to every farmer, because he has drifted into arrangements by which he is producing nitrate of potash, with little knowledge of the cause of a success which is generally satisfactory. Putting the matter in as simple a form as possible, it may be said that nitre beds are formed as follows: —**Good earth** is enriched by additions of sheep manure, or liquid **manure,** caustic **lime** is added, and the heap is occasionally turned over. Nitrate of potash is formed within the heap, and is separated by washing the earth. The changes which take place are briefly these: the nitrogenous matters in the manure decompose so as to form nitric acid; whilst the lime releases potash from its combinations in the soil,—just as mentioned on page 183; and by the union of the nitric acid and potash so produced we have the much-desired nitrate of potash produced.

The question will naturally arise, How does this arise in ordinary farm practice? First, in the formation of what are known as **compost heaps,** in which vegetable matter of various kinds is mixed with earth and quick-lime, with or without salt. Secondly, in the good old-fashioned system of putting **farm-yard manure** on the land at the time **the land was limed.** Many will no doubt remember the outcry raised against the good old custom, but success continued to attend the work in defiance of all the warnings. The warning voices were in error, because there had been an oversight, which made all the difference between success and failure. The **farm-yard manure,**

having been spread on the land, was **ploughed in.** The **quick-lime** was then spread over the surface and **harrowed in,** so that **the contact took place in the soil** under conditions favourable for the production of nitrate of potash. If the lime and farm-yard manure had mixed on the surface of the ground, much of the ammonia of the dung would have been dispersed into the atmosphere. **Successful practice** had thus drifted many a farmer into a system which was found to yield **good results,** but the **why** and the **wherefore** were **unknown.** Many will be disposed to make the further inquiry, If the system proved to be so successful, why do we see it so rarely carried out at the present time? It may be said in reply that it has been gradually discontinued in favour of smaller outlays, quicker returns, and decreased profits.

CHAPTER XXXIX.

ANOTHER reason for the application of **lime** is the fact of its being required as **a food for plant-growth.** Every crop we grow upon the land makes its demand for lime; and if our crops are to be produced in a luxuriant condition, and if we are to secure an abundant produce, there must be a sufficient supply existing in the soil in a condition ready for acting as plant-food. Thus far we have noticed lime as **preparing other substances** for becoming

plant-food, but now we have to regard it as being in itself necessary for taking **its own share of duty within the plant.** For this purpose lime is quite ready after it has served all its other duties. It has then become changed into the original condition of carbonate, and hence it is that whether lime has been burnt or not, it is in both stages competent for this duty. The chief supply of lime **as food** may be supposed to enter the plant **as Carbonate of lime,** dissolved in water containing carbonic acid, and this is generally the case in rain water. We may therefore accept this rule in reference to lime, that when it has to be used as a supply of plant-food, there is no necessity for its being burnt in the kiln. We have lime treated in this manner to prepare it for doing some of its work more quickly and more powerfully than it otherwise could, but it is ready for this duty of becoming food for plants when in the condition of carbonate of lime.

There is another duty which **lime** discharges in soils which yet remains to be noticed. We have seen it **acting chemically** upon other materials, and we have noticed it as being **acted upon** by other chemical agencies, until it enters the plant in a clear and bright liquid. In its early influence upon the soil, **the burnt lime** exercises a strong **mechanical influence,** which is especially observable in the case of **strong clays.** These soils are said to **become lighter** under its influence. This does **not refer to the weight** of the soil, but to **the *horse power*** necessary for its cultivation. The

land is **more easily** ploughed, harrowed, rolled, etc., by the lighter condition given to it by burnt lime.

Although **burnt lime** is a most valuable manure, and does **a great variety of work,** we have **lime in other conditions** which is also capable of doing **good work** for the soil. There are many cases in which these other forms of lime meet the requirements of some of our soils **in a more satisfactory manner** than the burnt lime could accomplish it. Lime is ready for use upon our farms in the form of **chalk,** as **marl,** and as **shell-sand.** Each one of these has its own special capabilities, and **for each there is a work** waiting to be done. As a rule each of these are used within a few miles of the places where they exist naturally, but burnt lime is often sent to much greater distances.

Chalk is capable of doing much of the work which is accomplished by burnt lime. It is quite capable of **neutralising the organic acids** in the soils, but it acts much more **gradually.** It also slowly assists in decomposing **organic matter** in the soil, but it does so in such a gentle manner, that it can be used **with perfect safety** on soils where the burnt lime would be most objectionable. It is also useful as **plant-food** on all soils. Its action upon the physical condition of **heavy clay soils,** although very different to that of burnt lime, is equally serviceable as a general rule, because it is used in much larger quantities, and when properly applied it very quickly blends itself into these soils, and **mixes with them.**

Chalk is **applied** upon the surface of the land in **the winter** months, and the field which has received a dressing of chalk presents a very white, stony appearance. The chalk is dug out of the chalk-beds in a **moist condition**, and this moisture is **not allowed to dry** out of it by digging it in hot weather. The raising of the chalk is delayed until the winter has commenced, in order that the water may remain in the chalk. The first **frost** that comes upon the chalk changes the **water** in it into **ice**; these particles of water as they become solid **take more room** than they did before—they become larger as they freeze. The result is that something must give place for the freezing water, and the **particles of chalk are separated** in the struggle. We do not see this so long as the frost lasts, but when **the thaw comes** the lumps of chalk **fall into pieces,** and are ready for mixing into the soil whenever a proper time comes for it to be done.

If we disregard this influence of the **moisture,** great **trouble** frequently arises. Fields have often been dressed with chalk **too late** in the winter, or possibly the winter has been unusually mild, or it may have ended earlier than had been expected, and the farmer finds himself in an unexpected **difficulty.** The lumps of chalk remain upon the surface waiting for the frost; but if it does not come, the **chalk becomes dry,** and as it dries it **hardens.** The trouble thus caused to the farmer is beyond all description, but he **never forgets the lesson** as long as he lives. As the summer advances the chalk gets

thoroughly hard and dry, and when the wet season again sets in the water soaks into it slowly and not very deeply. A frost is welcomed, but the work is far less perfect than before, for it is only the moist portion which is affected by the freezing. Thus it takes a series of showers and a succession of frosts to complete the breaking up of the chalk.

There is much difference in various chalks as manures. It is true that where the mechanical action of chalk is alone sought for, there is no material difference observable. It is, however, a very general rule, that the most fertilising chalk is desired, for the sake of its better influence on the great majority of soils. Thus farmers have gained by experience a certain knowledge—more or less indefinite—by which a preference is often given to beds of chalk, situated many miles more distant than other supplies. There was a time when farmers were thought to be in error in doing so, but microscopic examinations and chemical analysis have thrown a very valuable light upon the facts, and we now see the reason for a preference having been shown.

Thus we learn that there are considerable differences in the character and composition of chalk. We find in some chalk beds numberless shells of the most minute character, and we also find considerable variation in the phosphoric acid present. Thus the experience of the farmer finds an explanation at the hands of those who have familiarised themselves with scientific research. Having regard to the many great and important truths em-

bodied in the experience of farmers in all parts of the kingdom, it cannot fail to cause a surprise that they have discovered so many truths which science unfolds to our view in its clearer light. It should teach persons caution, in so very freely throwing censure upon well-established local customs, for many are the cases in which the hasty judgment of the stranger, has to be corrected by evidence accumulated through many a bygone year.

CHAPTER XL.

THERE is a class of earthy matters commonly known as marls, which are often used as manures for adding carbonate of lime to the soil. They differ from chalk in the very variable percentage of carbonate of lime they contain, for whilst chalk consists almost entirely of carbonate of lime, we sometimes find in marls as much as eighty per cent of this substance, and in other instances only two or three per cent. In the case of chalks we are, for all practical purposes, securing a supply nearly the whole of which is carbonate of lime; still it does contain some impurities, and these are sometimes valuable. In the use of marls we have no similar certainty as to their composition, because they are so very variable in their ingredients. It would, however, be a serious mistake to imagine that for this reason they are not valuable as manure. On

the contrary, in the neighbourhoods where these earthy beds exist, there is, generally speaking, a tolerably accurate idea prevalent as to their value upon different soils. Here we have more or less imperfect information arising from the use of such marls upon the farms around. At the best such information is only of local value, and strictly limited to the materials which have been experimented upon.

As soon as we have these marls examined, and their composition made evident by chemical analysis, we then begin to see why the different marl beds have gained a greater or a lesser reputation. In the following table we have the analyses (made by Professor Way) of three of these marls, and they may be taken as illustrating some of the variations in composition which are found in these fertilisers.

The information given in this table of analyses is not supposed to be remembered in detail, but there are certain lessons which may be borne in mind with great advantage. In the first place we see how great is the variety of substances found in some of our marls. Then we see that the presence of phosphoric acid and potash in the green marl in so large a proportion, is sure to make it a valuable manure. We may also note that in this marl nearly the whole of these two fertilisers are soluble in weak acids, and we may learn from this fact that when they are added to the soil, they would be easily made useful for plant-growth. Another re-

markable feature in this marl is the large percentage of **silica** in an easily **soluble form.**

	Green Marl.		Gray Marl.		Chalk Marl.	
	Soluble in dilute acid.	Insoluble in dilute acid.	Soluble in dilute acid.	Insoluble in dilute acid.	Soluble in dilute acid.	Insoluble in dilute acid.
Silica . .	31·88	22·06	2·16	16·68	2·11	5·42
Carbonic Acid .	trace	...	29·96	...	36·73	
Sulphuric Acid	·45	...	·21	...	·06	
Phosphoric Acid	3·76	...	·21	...	·05	
Chlorine . .	trace	...	·08	...	·04	
Lime . .	5·61	1·52	41·52	1·71	49·16	·22
Magnesia .	·85	1·09	·30	trace	1·18	trace
Potash . .	3·21	·45	·26	·32	·11	·15
Soda . .	1·20	·31	1·64	·07	1·36	·05
Oxides of Iron .	16·91	5·75	2·20	2·57	1·74	1·42
Alumina . .	·74		·11		·20	
Water and Loss	4·21					
	68·82	31·18	78·65	21·35	92·74	7·26
	100		100		100	

The other two samples of marl (the gray marl and the chalk marl) do not differ from each other, as much as the first did from both. These are marls which contain a large percentage of **carbonate of lime,** and the other substances which are intermixed form but a small portion of their bulk. Even here we see a larger proportion of fertilisers in the gray marl than in the chalk marl. The action of these **marls** when applied to the land would **differ** according to the useful character of the substances they contain. It need be no matter of surprise that

those who have used marls varying in composition and quality, should observe proportionate differences in the results. Experience thus gained is valuable, but chemistry explains why they have been more or less successful, and in many cases it will show a cheaper source of supply for the same materials.

The use of marl is often adopted for other reasons than the simple addition of fertilising matter, for in many cases marls are exceedingly useful in altering the mechanical condition of our soils. In the case of soils having too much sand, and which are comparatively unproductive in consequence, we see very great improvements resulting from an application of marl. The soil has greater power given to it for holding manure, for keeping a proper amount of moisture, and it becomes more productive by reason of the plant having a better supply of food and more favourable conditions of growth. The custom of using marls is one of very great antiquity: it was stamped with success many centuries before we knew the causes which led to that success, and it is by no means improbable that we may again find it wise to return to their more extensive use. It has been an increasing fashion of late years, to insist upon a supply of fertilisers which will act with great rapidity. The fact is that the quality of the produce has been injured, and has in far too many cases been entirely overlooked and sacrificed for securing rapidity of action. So long as all the conditions of successful growth are fully pro-

vided, there need be no objection raised to rapidity of action; but just in proportion as a high pressure system of production may be adopted, so does it become the more important to take care that we do not overlook any of the essentials of success.

Another natural manure of the same group remains to be noticed—the shell sand. In some districts this is a very useful and valuable fertiliser, but its use is very largely limited to places within easy reach of the deposits. These exist upon various parts of our coast; but of these the accumulations on the coasts of Cornwall and Devon, on the western coasts of Scotland, and on the northern coast of Ireland, are the largest. This sand consists of finely broken shells, and is composed chiefly of carbonate of lime, occasionally intermixed with small quantities of animal matters.

The series of natural manures in which lime forms the prominent constituent are certainly of great importance to the agriculturist. We have seen that in many instances they are powerful agents, which, when they are imprudently used, are capable of doing much injury to the soil. They are also very valuable promoters of fertility when prudently employed; but the important truth must never be lost sight of, that just in proportion as we use lime upon our ordinary soils, under conditions which make it more than usually stimulating, so is it likely to become very exhausting to the land, unless we secure a good supply of farm-yard manure to balance the demand made upon the soil.

PART THE THIRD.

CHAPTER XLI.

Artificial Manures are of comparatively recent introduction, but their use has become very extensive. It appears scarcely possible that within a period of about forty years, this class of manure should have been introduced and secured such a powerful hold upon the farmers of England. It certainly tends to show that these manures were needed, and that **they have done good service** upon the soil. The first consignment of Peruvian Guano consisted of thirty bags sent to Messrs. Myers and Co. of Liverpool in 1839, and when the Royal Agricultural Society of England held their meeting in Liverpool in 1841 a sample of the first cargo was exhibited by Messrs. Skirving of Liverpool as a novelty. Here then we notice the commencement of a new branch of commercial enterprise, which has grown to gigantic proportions, and allowed of many large fortunes having been made, by the profits which it yielded to those engaged in the business.

The Peruvian Guano must be allowed to have held a distinguished position from the period of its introduction into this country. From a very early period in its history, it was reserved for tolerably **direct sale** to those who were ready to use it upon their farms. Thus the manure was held **free from adulteration,** consequently for a long period it was not only the richest, but relatively the cheapest form of artificial manure. What would be thought now of a manure containing, on the average of 32 cargoes, 17 per cent of **ammonia,** besides from 20 to 30 per cent of **phosphates?** Even now it would be worth above £20 a ton, and it is therefore no wonder that so many millions of British gold have been paid away in exchange for it.

This manure is the **excrement of sea-fowls** which accumulated through centuries, without being injured by rains. It was found on the islands off the coast of Peru in enormous quantities; in fact some of the deposits were over 200 feet in depth. The richest deposits were first used, and the present supply is of **less strength** than formerly, and is consequently sold for **less money.** It is pre-eminently **an ammoniacal manure,** and the **phosphatic** material with which it is intermixed exerts a **secondary,** but still a very important influence. Much of its early success may be traced to the fact of both of these manures being thus blended in the same material. The ammonia was rather less active than some ammoniacal preparations of more recent date—as, for instance, sulphate of ammonia—and yet

it was quite fast enough for any land. Then again much of the phosphate had been changed from the somewhat insoluble form of bone earth into a more easily soluble form, and the consequence was that both were ready for tolerably prompt action. The influence of this early supply of Peruvian guano upon strong clay soils was unequalled by any opposing manure. It could only be purchased by cash payments, and this checked its use; but when the means for purchasing were at command it may be safely said to have been "the favourite manure" for strong clay soils.

Upon lighter lands it did not maintain an equal supremacy, but even here it was found exceedingly valuable, and at the present time the Peruvian guano maintains a very high character. The circumstance which limited the sale was the cash terms on which alone it could be sold; whilst the great majority of competing manures were sold on credit, which naturally compelled many to select that for which the payment could be postponed. On the other hand the integrity of the Government agents was—and is—a sure safeguard as to quality.

Bones had been used upon land in a more or less broken condition before the introduction of the Peruvian guano, but there was such slowness about the results that the expenditure was almost looked upon as a permanent investment to be made by the owner of the land, and on which the tenant paid an annual interest. Gradually the size of the bone was more and more reduced, resulting in more

and more rapid returns. It was even then a very slow work, and the contrast of the brilliant dash of the Peruvian guano **led persons to desire something more active.** The discovery which Liebig had made met the difficulty, for he introduced a plan of treating bones with sulphuric acid, and thus producing what was known as "Dissolved Bones" and afterwards as "Superphosphate of Lime."

The change which was accomplished is exceedingly simple, and needs but little attention to understand it. The principal ingredient in bone is **phosphate of lime,** and this is a substance which consists of two bodies—**phosphoric acid** and **lime.** There are three compounds consisting of these two bodies, which differ in character because they are combined **in different proportions.** If, as is usually the case when bone has not been treated chemically, the phosphoric acid has **three equivalents of lime** combined with it, then we have **slow decay** taking place. But if by any means we can remove two of the equivalents of lime, and **leave only one behind,** then we have a form of phosphate of lime which **dissolves in water very rapidly.** For this reason also when it was used upon the land as a manure the **crops grew very rapidly,** and the money expended in the purchase was very quickly repaid. Here then we had a manure which could act as quickly as the Peruvian guano, and these manures naturally became **rivals for favour.**

This **active** form of phosphate was soon known by another name—**superphosphate of lime**—and

it was so called because the phosphoric acid which belonged to **three** equivalents of lime had thus been **concentrated upon one** of lime, and this consequently had **an over-dose** of phosphoric acid, giving rise to the term **super**-phosphated lime. Thus the superphosphate of lime and the Peruvian guano became the contending rivals for public favour.

Scarcely had the contest begun before the important discovery made by **Dr. J. B. Lawes**—that he could obtain phosphate of lime from **rocks** as well as others could from **bones**—came into operation. For a time it was doubted, but the truth was eventually confirmed, and few can estimate, even approximately, **the enormous advantages** which the public derived from this discovery. The new product was known as **mineral** superphosphate of lime, as distinguished from **bone** superphosphate of lime. The limited supply of bone would soon have caused the price to advance to a very high rate, but as soon as it was known that phosphate could be found in rocks, and other deposits, large supplies were soon found. From various parts of the world these supplies were forthcoming. Spain, Portugal, Germany, West Indies, and United States, competed for the supply of the unmanufactured phosphates, and **the price was moderate.** Year by year the requirements increased, manufactories were enlarged, and became more numerous. When the race had fairly begun, the pace was so persistently quickened, that at length in every market town in the kingdom clusters of manure agents encouraged the sale of

artificial manures, under the pleas—of personal favour to the seller—the very great advantages of having what he recommended as the best manure—a low price—and with a considerable allowance of credit.

CHAPTER XLII.

The various inducements which were held out for securing orders for various manure firms, and the ease with which superphosphates were obtainable, did not prevent many a loud and strong protest. Many of those who had used bone before the dissolved bone or superphosphate became so general, continued to hold to the opinion that if they could have bone supplied in a sufficiently fine condition, they would give a distinct preference to this form of phosphate. As time rolled on the numbers steadily decreased of those who had any personal knowledge of bone as a manure. It is only fair to say that the strongest protests came from the sandstone districts, in which the decomposition of bone took place freely. The complaints and remonstrances of the few—were lost amidst the success of those who relied upon superphosphate and other very active manures.

One curious circumstance was observable amongst those who were reluctantly compelled to use the superphosphate, for their desire was to have some which had been made in the previous season. They had no reason for making this prefer-

ence, other than the fact that they found it more effective on the land than newly-made superphosphate. We know by chemical examinations that there are material differences in the composition of superphosphate consequent upon this storage. If a genuine bone superphosphate be placed in store for six or eight months, we find that the percentage of phosphate which is in a soluble condition decreases considerably. It might, when first made, contain 28 per cent of phosphate in a soluble condition, but after keeping it for some months it might only contain 18 or 20 per cent of phosphate in a soluble condition. It was in consequence of this (apparent) loss that such superphosphates were known as "reduced" superphosphates, and it was these "reduced" superphosphates which were very often most highly valued.

The standard of valuation on the market was the percentage of phosphate in a soluble condition; hence such "reduced" superphosphates, if sold by the accepted standard, involved loss to the manufacturer. The fact that in this "reduced" condition the manure became more valuable to the farmer was thus rendered a matter of secondary moment; the manufacturer was compelled to produce it in that form which met the market requirements rather than the farmer's. The contest continued for many years, and a loss was in many cases thrown upon farmers, and often upon the manufacturer also, by the standard of valuation being the percentage of phosphate in a soluble condition.

Gradually the manufacturers adopted the plan of using an excessive quantity of sulphuric acid, and thereby the "reduction" of the superphosphate was prevented. The manufacturer found that it was a smaller loss to waste sulphuric acid than not to be paid for that portion of the phosphate which had "gone back" in the strength. In January 1873 the author drew attention to this subject by a paper read before the Royal Dublin Society, in which the following remarks appear:—

"Under certain conditions of soil and climate, we shall doubtless find it desirable to carry forward the manufacture (of superphosphate) as at present; but it may be stated, with equal confidence, that under other circumstances this will not be done. This, however, can only be determined by a series of careful experiments in the field. Embodied in this question there is an annual saving for the manufacturers supplying the United Kingdom of from £100,000 to £200,000; and for the consumer probably four or five times that amount. It is, therefore, a very serious and important matter for both parties. That there are difficulties connected with the estimation of these "reduced" superphosphates no one for a moment doubts; but difficulties, when they are discovered, receive but one treatment—they are surmounted. To carry forward the manufacture beyond what is, in the opinion of the maker and the buyer, most desirable, simply to meet the present accepted mode of estimating the value of superphosphates, is so manifestly against public interests,

that when the truth is recognised the practice must cease."

We have advanced considerably since that time, and the "battle of the gauges" is now being renewed in the form of deciding upon the relative advantages of a greater or less solubility of the phosphates used as manures. Most heartily may the Aberdeenshire Agricultural Association be congratulated upon the great success which has attended the experimental research carried out by their able chemist, Mr. Thomas Jamieson. Other societies and experimenters are nobly following up the inquiry. During the last season (1880) a very interesting experiment was tried by Mr. J. H. Thursfield (Barrow, Shropshire), which may be here recorded as a somewhat typical example. He had for several years found decided advantage by "reducing" the superphosphate for his own use, as he could not purchase "reduced" superphosphate. He adopted the excellent plan of adding one ton of quarter-inch bone to every two tons of superphosphate. The bones are moderately moistened, and then mixed into a heap with the superphosphate. In a few days great heat was produced, and this heat continued, but after five or six weeks the manure was ready for use. The practical result of this action is to reduce the solubility of the superphosphate, and increase the solubility of that of the bone. The superphosphate was improved as a manure, but it was spoilt for analysis by reason of its having so little phosphate remaining in a soluble condition, and this is necessary

for the market standard. It would occupy too much space to go into fuller detail, but the result proved that 27s. expended in this manure produced as heavy a crop of swedes, and of as high-feeding quality as 45s. 6d. spent in other artificial manure of high quality, with ten loads of good farm-yard manure in addition. This is no solitary case, for much confirmatory evidence has already been given,[1] and more will be forthcoming.

This is not a question of any attack on the vested interests of the manure trade, but it is the adoption of measures calculated to promote the welfare of a very much larger vested interest engaged in the cultivation of the soil. If those engaged in the manure trade are not checked from exercising their judgment —which is singularly extensive—by market standards, which are objectionable, they will be as anxious to produce that form of manure which will be most beneficial, as the farmer will be desirous of purchasing it. That there has been a vast amount of good work already done by the aid of chemically-prepared manures cannot be doubted, but it may be very safely asserted that we are only on the threshold of the work. The success of the past has rather "rushed" us on too fast to make thoroughly safe work; the present times of difficulty have made all of us pause and consider whether we cannot improve and, if possible, perfect our system of manuring the

[1] The experimental researches carried out by D. v. Köth (*Bied. Centr.* 1879, 805), and those of A. Petermann (*Bied. Centr.* 1880, 87) may be especially mentioned.

land. The greater the success which may be attained in this direction the better for the agriculturist, and his ability to expend money in the purchase of artificial manures will increase with such success. If **the farmer's success** be made **the chief object,** the work done will equally benefit the vested interests of those engaged in the manure trade, and hence **the sooner all idea of anything like opposing interests is set aside,** the better for all interested in the welfare of the land.

CHAPTER XLIII.

BEFORE leaving the consideration of the preparation of bone and other phosphates of lime, it is necessary to notice the strong tendency of the evidence we have received from those engaged in the cultivation of the soil. The desire which was entertained by many who had used **bone** as a manure to continue its use, but in **a finer and softer condition,** led to its being softened by **fermentation,** and more recently has led to its being treated with **super-heated steam.** In both of these cases the phosphate of the bone is presented for plant-growth in a very convenient form, and ready for early use by the growing crop, **without being in that very soluble form** which induced the plant to make a growth far too rapid for its future well-being. Then again we have the preference shown for "**reduced**" superphosphate—we will not say in all cases—but at any

rate in very many districts. These facts render it necessary that mention should be made of a form of phosphate which is intermediate between the very soluble phosphate produced in superphosphate of lime and the very slowly soluble phosphate of lime existing in bone, and in mineral phosphate. This intermediate form is a slowly soluble phosphate, and it is that which is produced in the soil when bones undergo a natural decomposition by the assistance of rain-water and atmospheric air. When Liebig endeavoured to produce artificially and in a few hours, that which takes place naturally in the course of months or years, he did not imitate the model with accuracy. He produced a form of super-phosphate of lime, in which only one equivalent of lime remained, but this is never produced in the soil under the natural decomposition of bone. He overshot the mark, and he over-manufactured the material; hence it is that when it "goes back" and becomes a "reduced" superphosphate, the experienced farmer detects an old friend, and wishes to renew the acquaintance. There is a perfect consistency on the part of the cultivator of the soil, and although he values a supply of phosphate, he very often desires it in that intermediate condition of solubility which he knows to be most suitable for his land.

Many of the experimental trials between the (so-called) insoluble and soluble phosphates are carried out under conditions which will probably delay the final conclusion, but cannot possibly arrest it.

The mineral phosphates which are used are very frequently varieties which have been specially selected for manufacturing purposes, because they do not cause a waste of sulphuric by reason of the carbonate of lime, etc., which they contain. This is not a desirable form of mineral phosphate for the trial, for even if the trial goes against the unmanufactured phosphate, it must be appealed against when the best form of phosphate is made use of. It may be said that that form of mineral phosphate which is rejected by manufacturers (and also by shippers at present) because the phosphate of lime is in association with carbonate of lime and iron oxide, will in all probability be the most satisfactory to use in an unmanufactured form. However fine the phosphate may be ground, a period does arrive when we have to deal with the minute fragments to which it may have been reduced. If such particles are like some of the ground Canadian phosphates,—small, but still hard as glass,—it is evident that the rate of solubility must be excessively slow. But if such minute particles contain still more minute portions of carbonate of lime and iron oxide, these become dissolved out, and in doing so their removal will favour the solution of the phosphate which is left behind. The fundamental truth on which success in the trials now going on must ultimately turn, is that some mineral phosphates are better adapted than others for use in an unmanufactured condition.

We must also recognise the fact that there are other forms of phosphate, besides the phosphates of

lime, which must sooner or later command consideration. Phosphates of alumina and iron cannot be kept in the background. These have their regular spheres of action, and these must be determined. During the summer and autumn of 1880 some experiments on the growth of swedes were carried out at Felhampton Court, Shropshire, by John Hill, Esq., the President of the Marshbrook Agricultural Society, which throw a ray of light upon the action of the phosphate of alumina. In this case redonda phosphate (which is a phosphate of alumina), ground to a fine powder, was tested against superphosphate, superphosphate reduced by bone, and also by mineral phosphate, and against superphosphate strengthened by sulphate of ammonia. The trial was conducted with every care, and the results were as follows :—

Plot.	Manure sown per Acre.	Cost per Acre.	Produce per Acre. T. C.	Remarks.
1	5 cwt. Superphosphate	20s.	26 17½	
2	5 cwt. Redonda Phosphate, 2½ cwt. Superphosphate	30s.	25 0	Rather damaged by fly.
3	2½ cwt. Superphosphate, 119 lbs. Bone Meal	20s.	25 1½	
4	5 cwt. Superphosphate, 108 lbs. Sulphate of Ammonia	40s.	22 17½	Rather damaged by fly.
5	2½ cwt. Superphosphate, 2½ cwt. Redonda Phosphate	20s.	26 0	
6	No Manure.	...	7 6½	
7	5 cwt. Redonda Phosphate	20s.	30 0	Much choked by charlock.

Other instances might be given of the value of phosphates of alumina and of iron, but this will serve as an example. We shall no doubt be able, at no very distant time, to use each and all of these phosphates, **as and where** they will do the best service; but in the meantime it is necessary to recognise the fact that the fertilising properties are **not restricted to any one kind of phosphate.**

In the above experiments we also see another example of the influence of the sulphate of ammonia. It is an exceedingly common idea that **a good manure must be a good fertiliser,** but in this trial (and there are very many others) we found that it was **a good manure in the wrong place,** and that it not only caused some decrease in the crop, but, from other observations taken, and which will be subsequently referred to, it was evident that it had produced a swede of decidedly **lower-feeding value.** In the majority of trials which have been made with different fertilisers, **the quality** of the produce **has not been sufficiently considered.** A moment's consideration will show that this is a most important element in the calculation of the results. Many indeed are the cases in which **farmers have protested** against the use of certain manures, knowing that the sheep did not progress upon the "roots" so grown as well as they should have done. They have not simply to obtain so many tons of produce, but rather to secure in the crop the largest percentage of sound feeding matter.

The difficulties with which farmers have had to

contend have been most serious, but few, if any, of them have interfered more with their attaining to the highest success, than the mystery which has been thrown around some of the best manures which they have used. If an agriculturist be an intelligent man, and if he knows what materials he has been using, he will soon indicate which of the supplies may be most advantageously strengthened. The special manures prepared for certain crops are generally composed of well selected materials, and these are mixed according to the judgment of the manufacturer. But in order that they may provide for variations in the demands made by the soil, materials have to be added which are not always necessary, and to the farmer that is so far a source of loss, because he has to pay for something which is not necessary for his land. Careful experiments will in a few years do much to satisfy any farmer upon the mixture of fertilisers which he should use upon his farm, but there will always be room for improvement, and for the exercise of a true economy in the proper selection of artificial manures.

CHAPTER XLIV.

It is not many years since that analyses were frequently presented to buyers of artificial manures for their perusal, which were completely condemnatory

of the manures offered for sale. This was done to satisfy the buyer, by means of a document which he could not understand, and it therefore made little difference what were the details of the information which it furnished. The time has gone by for such deception, but it has now taken a new form in the hands of some persons. For present purposes **manures** are often **made to analyse well,**—that is to say, the manures are made to analyse better than they really are. This is especially the case with some manures, in which the nitrogenous matter is supplied by substances of inferior value.

Take a case in point. A manufacturer prepares a manure for a special purpose, and if he is allowed to supply it at fair trade terms, he can afford to, and very generally does, compound it of the best materials. If the buyer considers it too dear, he often practically forces the maker **to sell it on analysis,** and it may be that he cannot sell on such terms, because his materials are **too good and costly.** Assuming, for instance, that prepared bone and dried flesh had been introduced into the manure because their action is so thoroughly good, yet to meet the conditions of analysis **cheaper substitutes** might have to be used, which would evade the claims of the analysis required. Cheap and very inferior substitutes are called in **from absolute necessity,** when the manufacturer would far rather have supplied the better quality manure. This is another misuse of chemical analysis, but this is not so much the error of chemical analysis as it is the fault of those who

do not use it with discretion. There are manures which the makers cannot sell on the basis of their analysis, especially when the ordinary standard market values are to be made use of. These **special productions** must be dealt with as **exceptional preparations,** and they must not be forced under standards of valuation which do not apply to them. The improper use of chemical analysis in no way diminishes from the value which attaches to its fair and legitimate use. Exceptional preparations should be fairly described to the buyer as being exceptional, and, as a rule, good judgment will be shown; but the buyer must not think that under such circumstances chemical analysis is necessarily a fair arbitrator. If it be **unwillingly submitted to,** it may be with a determination **to evade its test.**

There is a large number of different materials sold upon the market as artificial manures, a description of which will be found in other works, and they are consequently not detailed here; but it may be convenient to notice that a great difference exists between those which **enrich the soil** and those which **exhaust it.** An instance illustrating the latter case may be mentioned. Two farmers occupying adjoining fields, of very similar natural character, purchased some nitrate of soda from a merchant. It was applied in equal quantities and in a similar manner in both cases, but in the one case an excellent crop of corn resulted, whilst in the other instance no advantage resulted. An examination of the circumstances led to the conclusion that the one field was

in good condition, but the other was poor and exhausted. The use of the whip in the one case quickened the pace, but in the other instance there was not sufficient strength to respond to the stimulus given, and the advantages gained did not even pay the cost of the whip. In the latter case a more liberal supply of food (plant-food) was needed rather than the attempted flogging. It is not the only case we see of "more food less whip" being desirable, but it must be remembered that when the use of the whip is necessary, the consequent exhaustion of the soil should always be liberally provided for.

A prudent and intelligent farmer will also recognise **the true duties of an artificial manure.** In his mind there is **no rivalry** between it and farm-yard manure. He knows that if he regards the farm-yard manure as containing "**some of the freehold,**" it demands every care and a proper return to the soil. With all his care he cannot thus return to the soil **all** he has drawn from it,—therefore **supplemental help is necessary**; and herein he sees **one of the duties** to be performed by artificial manures. Cases will arise in which the **distant and difficult transport** of farm-yard manure, renders a light and portable fertiliser very much more advantageous. In the former case the artificial manure gave **supplemental** help, but in the latter instances it becomes a **substitute.**

But in selecting and determining the character and composition of the artificial manure, agriculturists even now naturally desire to follow on the lines

accepted by farmers fully thirty years since. If we let them know by chemical analysis what is present in a soil in a condition useful for plant-growth, they will soon make a judicious selection calculated to meet the deficiency existing in this soil. This is one of the most urgent necessities which the farmer now asks from chemical analysts, and it cannot long be refused. He wants to be informed respecting the composition both of the active and also of the dormant constituents of the soil he cultivates, and it will soon be a matter of surprise that he has had to wait so long for the information he so urgently needs.

The system of selecting suitable fertilisers should long ere now have been reduced to some more definite system, instead of its being, as is now so often the case, simply an attempt to supply an unknown deficiency. As a consequence we have the most conflicting results from our experiments in the use of artificial manures. Millions upon millions have been lost by the purchase and use of unnecessary materials, and by neglecting to supply all that was required. It is the small supply of the smallest essential which limits the productive powers of the soils, and as we know more of our soils we shall probably find that instead of strengthening the weakest link in the chain, we have often been supplying new chains with a similar link still remaining weak and feeble. It is by no means improbable that cheap and inexpensive materials will, in special cases, become powerful

fertilisers simply because these **alone** were needed to make the land productive. The instance already mentioned (page 92) in connection with Professor Wolff's experiment is just a case in point. An **abundant** supply of fertilising matter was present, and in an available form, **but the plant was dying. A most minute supply of iron** enabled **all the rest** to be utilised, and **the sudden luxuriance** of the plant reminds one of the action of nitrate of soda in the full springtide of the year. When we fully understand the action of this nitrate our surprise will probably decrease, but meantime we may take Professor Wolff's experiment as a typical illustration of the absolute necessity of **the supply being perfect** in all the requisite materials, **whether they be cheap** or expensive to purchase. Whatever be the supplies we may need it will be but prudent to purchase them on the best terms, but circumstances will probably arise when, as in Professor Wolff's experience, **a very inexpensive supply** suddenly becomes **of the greatest possible importance.** We are safe in looking upon clear evidence as to any **deficiency in the supply** of plant-food needed for a crop, or for a series of crops, as **one of the foundation stones** on which to construct some definite policy for the manufacture and employment of artificial manures.

CHAPTER XLV.

The practice of irrigation has a twofold influence on the soil: it adds fertilising matter to the land, and it produces an artificial climate in the soil. In the first duty it constitutes an additional source of manure, and often of a most valuable character. Irrigation largely consists in passing water through the soil. It is not a mere saturation of the land, as we find in a swamp, but it is a supply of water which is continually in motion, and herein it may be contrasted with the water of swamp which is stagnant. There is a great difference in the influence of water under these two conditions. When water is rendered stagnant in the land, the air which it contains is soon drawn upon by the vegetation on the surface, and when this has been accomplished the access of a fresh supply of air is impeded by the accumulation of water which remains on the surface. Stagnant water injures vegetation, and checks its growth by preventing the atmospheric air being useful for promoting healthy growth. Further than this the decompositions which take place under stagnant water are unfavourable to vegetable growth. If we contrast with this state of things a steady current of water passing through the soil, we observe conditions which are eminently adapted for promoting healthy growth. The onward flow of water carries

a fresh supply of **atmospheric air,** the plant-growth is favoured by **a favourable decomposition** of the various matters in the soil, and in addition to these conditions for healthy growth there is **a constant supply of plant-food** brought within reach of the herbage or crop.

The waters which are used for irrigation purposes differ greatly in their composition, and they therefore differ also in **the materials which they convey to the land** for the use of the plants growing upon it. Spring and river waters are both used according to local necessities and the level of supply. All of these waters may be divided into two tolerably distinct groups—namely, **hard** waters and **soft** waters. That peculiar character which we describe as hardness in water, is commonly known to us in its curdling influence upon **soap,** by the deposit of **a crust in the kettles** and boilers in which it may be heated, and by the difficulties arising from its use **for cooking purposes.** It arises from the **carbonate of lime** which it holds in solution by the aid of carbonic acid, and in some cases also from the **sulphate of lime** which it contains. The usual means which local waterers adopt for testing these waters is by the softness of the feel to the hands; in other cases by the use of soap. Some waters feel **soft** and almost **greasy,** and offer a striking **contrast** to the hard water, and it will rarely happen that there will be any difficulty in classifying any water.

But **both** hard and soft waters **contain** other substances in solution; **potash, phosphoric acid,**

soluble silica, etc., are often present; and hence it is that some waters bring into the soil such large quantities of valuable **fertilising matter.** Some singular **differences of opinion** exist amongst those who are engaged in the management of water-meadows and those who construct them, so far as regards the **value of water** for irrigation purposes. If we take the western counties of England, we find a tolerably constant opinion amongst waterers, **that soft water is alone valuable** for this use. But in the counties of Wilts, Gloucestershire, and Hampshire, **hard waters are freely used** and with very **great advantage.** It has already been stated that the hardness or the softness of water does not give full information as to **other** fertilising matters which may also be found in water. This point of character—the hardness of the water—**cannot be taken as a safe guidance,** because, whether lime be present or absent, the water may still possess elements of fertility. At the same time it is **not safe** to act in defiance of local opinion, without having some sound reason for doing so. If by chemical examination it could be shown that the water of a spring possessed certain fertilising constituents, it would be unwise to condemn it for irrigation purposes. Still, as a matter of prudence, **local opinions are entitled to consideration and respect.** The presence of **trout** in any stream is generally accepted as evidence of the water being good for irrigation.

When a very large supply of water is passed through a soil, we are naturally led to consider how

it is that in its passage through the land any good results can arise. It may not unnaturally be thought probable that any plant-food in the soil would soon be washed out it, and carried away beneath soil, either into drains or into some porous rock beneath. Some thirty years have now elapsed since Professor Way's experiments were published by the Royal Agricultural Society of England, explaining the very important action which takes place in the soil. It was shown by these experiments,[1] that "the influence of **the water** was felt long after it had drained from the land, and that it **had left behind it in the soil** a rich manuring of those elements which plants delight in." Materials dissolved in water and added to a shallow bed of soil were **arrested by the soil** during the passage of the water. When that valuable fertiliser **sulphate of ammonia** was dissolved in water and added to the soil, the water passing from the soil contained **sulphate of lime,** the soil having secured **the most valuable fertiliser** and substituted another of less value. A solution of potash had very similar treatment in the soil, and the lesson which it taught was, that **water containing fertilising matter** was deprived of its more valuable constituents as it passed through the soil, and that **these matters were retained in the soil** ready for plant-growth. If any base was removed from the soil it was a substitute for some other substance of greater fertilising value.

An important application was soon made of this

[1] *Journal, Royal Agricultural Society*, 1850, page 379.

fact, by water being used as a means for distributing fertilisers over and into the land, instead of doing it by carts and hand labour. Mr. Robert Smith adopted this plan on some of the Exmoor hills on which it was desired to secure a good pasturage, but which needed manure to encourage the growth, and yet they were almost **too steep** for any application even of light and portable manures. The plan which he adopted was to make use of **a spring of water** on some high portion of the land, and this was conveyed by water-channels to a convenient spot, so that manures could be added to it as it passed through a large tank. The water was then conveyed away in a small channel having a very slight incline, and thus the water was conveyed around any lower portions of the hill. A small piece of slate was used so as to block the passage whenever it was desired to make the water run over the edge and trickle down the hill, carrying with it the fertilising matter which had been added to it. As one portion of the land was sufficiently watered, so the slate was removed from across the channel, and placed so as to turn the water over another portion of land. Mr. Smith went so far as to make a yard and shedding for stock at this high level, and **wash all the fertilising matter out of the manure.** It was found a very cheap and valuable means for distributing manure over lands which were difficult to enrich by ordinary means. The value of the arrangement, however, depended entirely upon **the power of the soil to separate the fertilising matter dissolved**

in it, for if the soil could not have done this, it would have been simply a means of wasting manure, and nothing more. It affords, therefore, a very good illustration of **the absorptive power of soils,** and the economic use of water as a **carrier** and **distributor** of manure.

CHAPTER XLVI.

A VERY curious instance of **land irrigation** caused much surprise for some time by reason of its **apparent contradiction** to the views already expressed. In the *Journal of the Royal Agricultural Society* just referred to, the late Mr. Philip Pusey added a note to Professor Way's Report as follows:—"It is remarkable that Lord Hatherton's meadows are **irrigated entirely from drains,** the water of which has, therefore, already undergone this very process of filtration before it fertilises the land." The author visited this estate at Teddesley not long after this; doubt had been raised, and the following are the facts of the case as reported[1] by him in 1858. "About 200 acres of very wet land situated on the highest portion of the farm at Teddesley had for its improvement and cultivation to be thoroughly drained. In doing so several strong springs were tapped. These when combined produced a permanent and abundant

[1] *Bath and West of England Agricultural Society's Journal,* 1859, page 156.

flow of water. This stream has been conveyed to the farm buildings, where it works a mill-wheel 38 feet in diameter, and gives a power equal to twelve horses. This power is employed for grinding corn and malt, sawing, carpenter's work, chaff-cutting, threshing, and other farm operations. After being used in this manner, it is conveyed away for the purpose of irrigating 120 acres of meadow-land below. The originality of this application of water, which was previously productive of so much injury to the land when stagnant, but is now rendered so valuable as a motive power and for irrigation, is perhaps scarcely equalled. It is now some years since I personally inspected these meadows, but I do not consider the action of this drainage water to be as contradictory as has been represented. It appears to me that the explanation lies in the fact that many fresh springs which had never passed through the soil were conveyed away in the drains, and hence had not come under this influence. Had the entire quantity of drainage water passed through the soil from the surface, very different results would have been seen; but if, as I believe, it arises from the fresh springs drawn off into the drains, the question no longer rests on the absorptive powers of the soil."

Thus far the advantages of irrigation have been traced to the direct addition of fertilising matter, but another influence is often exerted by it, resulting in an artificial climate being produced in *the soil.* Much of the water used for irrigation has

a higher temperature than the land through which it passes, and thereby direct warmth is imparted to the soil. We cannot trace any large share of the influence to this cause, but it may still be regarded as one source of warmth to the soil. In fact, cases have been noticed in which the beneficial influences on land decreased as the distance from the spring increased.

Most persons have noticed how freely vegetation is continued through the winter months, when the surface has been protected and shielded by any loose materials lying about on the surface. It was at one time thought to have arisen from the simple fact that these materials simply prevented animals eating the growth, which had been specially observed. This was definitely tested by Mr. Gurney, and the results of his experiments were reported in an article on the "Practice of Irrigation" by the author, published in 1859.[1] Mr. Gurney found that if rods of wood, iron, or any other material, were supported within one inch of the surface, an increased growth resulted, and the greater the width of the covering material the more evident was the effect. Flags, rushes, straw, bushes, or any similar covering produced the same effect. Reeds or wheaten straw applied over the grass at the rate of about a load or a load and a half per acre in a very short time increased the quantity of grass to an incredible extent. The various grasses under these coverings weré found to be healthy, and rapidly passed through their stages of

[1] *Bath and West of England Agricultural Society's Journal*, vol. vii. page 148.

growth—some growing, some flowering, and some seeding. One of Mr. Gurney's experiments was as follows :—

	Covered Land. Produce per Acre.	Uncovered Land. Produce per Acre.
Grass laid up April 15, cut May 30, produced .	5870 lbs.	2207 lbs.
Clover ley laid up May 2, cut June 2, produced .	3460 ,,	960 ,,
Trefoil in above . .	$3\frac{1}{2}$ inches	1 inch
Clover in above . .	6 ,,	$1\frac{1}{2}$,,
White Dutch in above .	1 to 2 ,,	none
Loss of water in making into hay . . .	$\frac{2}{3}$	$\frac{2}{3}$

An increased number of experiments tended to confirm the preceding results, and they added this important fact—that **the advantages gained increased with any increase in the natural fertility of the soil.** One experiment made by Dr. Vacy showed that a certain quantity of stall manure, which would **double** the quantity of grass when laid on in the usual way, was found to increase it **six times** when properly treated **with fibrous covering.** Dr. Vacy says,[1] "I made a careful analysis of the herbage produced by this action, and also that of the same ground left open, and the results were the same. The fattening properties seem to be equal weight for weight. They were tried on feeding cattle, milch cows, and store stock."

In the distribution of water for the irrigation of land the chief point aimed at is to spread the water

[1] *Journal of Royal Agricultural Society*, vol. vii. p. 279.

so **that it shall cover the land**; and when the surface is so covered the more completely the water can **then pass through the soil** the better. There are some modifications of this arrangement, as in the **catch-meadows,** where the water is **caught in a lower gutter,** and again distributed. This may be repeated again and again, but each time the water is thus caught it **recommences** its run **by an equal overflow,** which, of course, favours a fair distribution.

It will be seen that by irrigation we thus **throw a shield over the ground,** and one of a far more perfect character than we could secure by any ordinary fibrous covering. The effect of this shield, continued as it often is for three weeks at a time, is to produce **an artificial climate** in the soil, which enables us to produce **a spring growth during the months of winter. The length of time** during which the land is covered differs with the average temperature for the time. In cold weather it may be continued for **three weeks,** whilst in hot weather **one week** may be enough. The test which indicates that the land needs to be freed from water is **the formation of any scum** on the surface of the water.

In removing the water in the winter months special care is always necessary **to prevent the young and tender herbage being injured by the frost.** Under **the protection** of the irrigation water a young growth has been encouraged, and when the water is removed it is as if it were deprived of

an outer wrapper. If a frost should commence **whilst it is wet,** it will be seriously **injured.** The waterer, therefore, watches the weather, and only turns off the water when he is tolerably safe from frost; and then he does so in the morning, so **that the herbage may get dry** whilst he is on duty. If a frost suddenly returns **before the herbage is dry,** he will probably **turn on the water again for its protection.** The frost is always **much more severe** in its influence on vegetation **when the herbage is wet,** and the skilful waterer does his best to protect his young growth from it.

CHAPTER XLVII.

Irrigation is now very frequently carried out by the use of **sewage water** from towns, which differs from the use of clean water chiefly in consequence of the **impurities** it contains. These impurities occasion many difficulties, of which we have no knowledge whatever in the use of clean water. Another difficulty which has to be contended with arises from **the variations** in the character of the sewage water. Some persons have an idea that town sewage is of a tolerably definite character; but such is not the fact. If we described town sewage as **the waste of the town coming through the sewers,** it would be readily understood that this waste would differ. The trade and manufactures of a town, the supply of water

per head of the population, and various other conditions, influence this **most variable of all fertilisers,** town sewage.

There are some few cases in which town sewage has been utilised as **a source of fertilising matter,** but in the great majority of cases irrigation is used simply as the easiest way for so far **cleansing the town sewage,** that it may be allowed to pass into some river in a fairly passable condition. Thus we have **two perfectly distinct objects** in view, and **two distinct systems.** The agricultural interest most largely gathers around the former, and these cases are chiefly limited to towns in which no manufactures are carried on which are calculated to prejudice the fertilising properties of the sewage water.

Those instances in which the **town sewage** has been successfully applied for agricultural purposes are **not limited to grass land,** as is the case where irrigation with water has been carried out. It is found desirable, in many of these irrigation schemes, for the town sewage to be **applied to the ploughed land,** not only **whilst crops are growing** upon the land, but also **whilst the land is without crop.** In this way many an acre of land has had a strong dressing of manure, simply by the sewage passing through the soil. Land which is intended for a **corn** crop is generally prepared **beforehand,** as the sewage has a strong tendency to make corn "**run to straw**" rather than yield good crops of corn. The sewage is often applied direct to land growing

Italian rye grass, cabbages, mangel, and similar green crops. These crops make a good use of the supply, and when the town sewage has been well blended with the soil it becomes so far purified that the objections to its use are practically overcome. It is by no means equally satisfactory when the herbage becomes bathed in the sewage, and the adhering particles continue attached to it until it has been cut for use. Some decay of this matter so attached to the leaves will doubtless take place during the plant's growth, but it cannot be conducive to health for any animal to consume food which has any such undesirable pollution upon it. So long as such matter has been mixed with the soil, the purifying powers of the soil will make it safe and satisfactory for use; but the circumstances are very different when the herbage becomes clogged and coated with fœtid matter, and such herbage is then used for cattle, possibly dairy cows. Its use for the latter class of stock is happily on the decrease, but this only removes the chances of disease one step farther back, namely from milk to meat.

It has already been stated that sewage water differs greatly, and even in its special liability to cause an unhealthy condition of the animal body. A free supply of water to the town, a lengthened transit to the land, exposure to the air, and a large amount of agitation as the sewage passes to the land, each and all of these are calculated to render the sewage less injurious on coming in contact with the leaf. If the sewage matter only comes in contact

with the plant at its roots, the purifying action of the soil will render it a fit and wholesome food for the plant; but the same cannot be said when those portions of the plant which have to be consumed by stock are made offensive by it.

The soil is often made use of as a means for filtering sewage water. In these cases far more sewage is applied than is necessary or desirable for the growth of the herbage on the service; the produce of the land is a secondary consideration; the chief anxiety is to cleanse, in some degree, the sewage passed through the soil, so that it may cease to be offensive. The objections already mentioned, as attaching to the herbage being made foul, apply in these cases in an increased degree. Two agencies are here called in to aid the land to do as much work as possible in making a clean effluent water. The alternate periods of sewage purification and rest are one of these; for as soon as the land has arrested as much as its powers will allow, the supply of sewage being stopped enables the land to dry. The passage of the water from the soil draws the atmospheric air into it, and the conditions are then favourable for the decaying matter distributed through the soil to be, in some degree, oxidised and purified. The chief accumulation of organic matter will be on the surface, and its decay will speedily commence on its becoming moderately dry.

When the growth of herbage is promoted by well-conducted irrigation with water in a satisfactory condition, we obtain a greatly increased yield from the

land. Under such a system of growth we do not want to keep the land idle. For this reason the early crops especially are allowed to come to maturity, and are then cut and carried from the land. Immediately the ground is cleared it is again watered, and growth commences without any delay. If instead of doing this we allowed the sheep to run over the field and eat that which they prefer until the first growth had been cleared off, we should probably reduce the produce of the land to one-third or one-half. If irrigation is worth doing, it is worth doing well, and in order that this may be accomplished, we adopt every reasonable and prudent measure to have the intervals for growth interrupted as little as possible.

A good system of irrigation enables us to secure the produce of the land in a higher feeding condition than is otherwise usual. The analysis of early water-meadow grass shows that it is far more capable of promoting the growth and fattening of farm stock, than at any other period of the year. Besides this, there is the enormous advantage of being able, in March and April, to have supplies of newly-grown grass for ewes and lambs, instead of having to wait until May and June. To the flock-master a good supply of early water-meadow grass is of very great value, and the influence it exerts on the character of the milk and the growth of the lambs, shows itself through the season. Well-conducted irrigation demands considerable extension and more frequent adoption, but our success will certainly be

promoted by a clear perception of the objects we may secure by this system, and by a more intimate acquaintance with the principles which regulate the practice.

CHAPTER XLVIII.

WE have noticed two somewhat similar systems whereby **water** is used as a means for **conveying fertilising matter** to the soil. In the first place that matter was dissolved in the water, and the supply was clean and enriching to the soil. In the second place, in the form of town sewage, the water was made the vehicle for bringing to the land the very variable waste from our towns. In one other way water is also made to carry fertilising matter to the soil; this third method is known as **warping**. Some of our rivers are noted for a muddy appearance, which arises from their carrying a considerable quantity of very fine earthy matter. This earthy matter **floats in the water** so long as the stream **flows freely;** but when any of the water is removed in a glass and allowed to remain **perfectly quiet,** this earthy matter **falls to the bottom,** and the water becomes bright and brilliant.

The practice of warping is nothing more than doing on a large scale what has thus been described as being done in a glass. It can only be done in the immediate neighbourhood of some river having **muddy water,** and upon land which lies at **a**

lower level than the stream. The most extensive system of warping is that around the Humber, and here many thousands of acres of poor and barren soil, which had been embanked so as to protect it from the river water, were subsequently warped and made exceedingly valuable for tillage purposes. The water of the river having been **raised by the tide,** is allowed to pass through the embankment by means of proper sluices, and the muddy water thus **flows in upon the land** as it may be guided. It soon becomes **quiet and still** as a lake, the **fine earthy matter is deposited** on the land. As soon as the tide has fallen, the clear and bright water is allowed to flow out into the river, whilst the land has received a coating of very fine and beautiful earth.

This system may be carried out to a greater or lesser extent according to requirements of the land. In some cases a large extent of land has been raised 18 or 20 inches or more, and covered with the richest and most productive soil. It is therefore quite within command to allow more or less matter to be thus deposited on the surface, and it therefore becomes a valuable source of fertilising. It must be noted that we are, in such cases, receiving **a deposit of undissolved matter,** whilst the clear water is allowed to pass off into the river, carrying with it any matters which it may hold in solution. Thus it happens that—

In water irrigation	fertilising matter is added in solution.
In sewage irrigation	fertilising matter is added partly in solution and partly in suspension.
In warping land	fertilising matter is added in suspension.

These constitute **the three systems** by which **water** is utilised as a means for **conveying fertilising matter** to the soil. When such matters have been intermixed with the soil, they lose their individuality of character and simply become **constituents of the soil,** subject to those conditions and uses which have been already referred to.

The fact of **water** being made to act the part of **a carrier,** renders it necessary that there should be every facility for allowing the water to do its work in **the most complete manner.** Hence it is that it becomes a most important condition of success, that under **the two first systems** there shall be **a thoroughly good under-drainage** of the lands irrigated. If this condition does not exist **naturally,** it must be established by **artificial means.** It has been shown how largely the soil is enriched by the water passing through the land leaving in it valuable fertilising matter. This **passing through** the soil necessitates a **passing out** of the soil beneath, quite as much as a **passing into** the soil at the surface, otherwise there could be no passing through. Drainage, whether natural or artificial, secures **the necessary outlet,** and just makes the difference between the land being saturated by stagnant water, and having a health-giving fertilising stream passing through the soil. The **proper drainage** of the land must ever be regarded as an essential condition for **successful irrigation.**

The reasons for this are tolerably obvious. Vegetation needs **atmospheric air,** and cannot be de-

prived of it for any length of time without an interruption of the functions of life. So long as the irrigating water is in motion the plant finds that there is air in the water, and it makes use of it accordingly. This limited supply—useful as it may be for an emergency—is not fully sufficient for luxuriant growth, and this is one of the reasons why the irrigation flow is interrupted at certain intervals. It is absolutely necessary to stop the flow even of water—still more so of town sewage—so that the plants may breathe and flourish under less artificial conditions, and also to charge the ground with atmospheric air, which becomes, in the soil, an influential agency regulating the decompositions taking place within the land.

If the fertility of the soil is increased by these several modes of conveying fertilising matter to the soil, it must also be remembered that the conditions established must be utilised by suitable plants and crops. We speak of grass land as if it simply represented land on which one special crop is growing, namely, grass. But the herbage we recognise as grass consists of an immense variety of plants, and their study constitutes one of the most important sections of the science of agricultural practice. We have upwards of a hundred different grasses, and these groups differ according to the soil on which they are grown and its general condition as to water supply and climate. We must not imagine that if we drain a very wet meadow, or irrigate a very dry meadow, we simply increase the growth of

the grasses which may happen to be existing there. **Each variety** of grass requires **a definite set of conditions.** If these are favourable, it luxuriates; if somewhat unfavourable, the plant only makes a feeble growth; if very unfavourable, that grass either dies out or takes a form in which it passively endures the adverse conditions which surround it. If we **modify the conditions of growth** we thereby **change the herbage**; for instance, if a dry meadow be irrigated with water, some of the old grasses almost disappear, and some that have been unobserved spring into luxuriant growth. If the original conditions are restored, the probabilities are in favour of our restoring the old herbage. Meadows which are to be used for irrigation must be watched with care, for it may be that after all the conditions of fertility have been secured, the produce is very limited, because **suitable plants do not exist upon the land** prepared to make use of the new conditions which have been established. In such a case the seeds of **suitable grasses must be sown.** We frequently see just the same imperfect growth when some lands have been drained, and the herbage has almost disappeared. So great may be the loss of herbage, that many are disposed to say the land is **injured by drainage.** It has, no doubt, proved **unfavourable for** the plants previously existing there—low quality **aquatic grasses**—but new grasses suitable to the altered circumstances must be sown. It is a great encouragement to all good agricultural practice, that the higher and more fav-

ourable the conditions of fertility may be, the higher and more nutritious is the feeding quality of the food produced.

CHAPTER XLIX.

AFTER all the care and judgment exercised by the farmer in the preparation of the land for a crop, he has then to select suitable agents for utilising his previous work. The land may have been brought into that mechanical condition which best favours its productiveness,—it may contain satisfactory supplies of food,—and it then becomes the duty of the farmer to **select the seed** which is most suitable for doing the required work, in that climate and upon that soil. The choice of seed is obviously a matter of the deepest importance for the farmer's success.

Farm seeds of every kind have been greatly improved by various processes, and have thus been raised to their present character. **The general policy** has been to produce by artificial means more luxuriant conditions of growth, and then to **select** from the cultivated specimens those which promise to be **the most desirable** and suitable. The seed would not be allowed to fall and make a natural growth, but it would be preserved until the most favourable period arrived for luxuriant growth, and it would then be **sown under favourable conditions** for securing a still higher development. The produce of such seed would—under such favourable circum-

stances—in all probability be of **a higher type** of character than the preceding growth. Thus, by constantly selecting plants having the desired form of growth, we gradually give the seed of such plants a certain **permanency of character**, and an increased power of producing plants possessing like peculiarities of form. In this way accidental **variations have been established** as settled points of character. Each time any such variation is reproduced, there is an increased power acquired for its reproduction. In other words, **hereditary influence has been established**, and the foundation laid for pedigree character.

This rule applies to all our cultivated plants, but we may take wheat as an example. In each and every ear of wheat variations are found in the character of the individual grains. Thus some grains will be larger than others, some will be finer in the skin and of higher quality, and thus very many differences will be observable. Each of these grains of wheat will have **a tendency to produce** other grains of wheat possessing **similar peculiarities.** In some cases these peculiarities will become even more distinct. This selection of those grains having the desired peculiarity of character will probably result in **a larger proportion** of grains which are **so distinguished** being produced in each succeeding growth. In this way a certain permanency of character is established. But it must be distinctly understood that it needs equal if not greater care and attention **to preserve these peculiarities** of form,

as it does to secure for them their original character. It is **not** a permanency of character which is established, so much as a condition favourable for reproducing certain variations from the original type ; and this needs proper care and attention.

The improvement of **farm seeds** has been greatly encouraged by the production of **new varieties**, by blending different growths whilst the plants are in bloom. Even here the same selecting care and judicious culture is necessary. The question may be asked :—Wherein consists the advantages of such new varieties? One great advantage is, that instead of dealing with **accidental** varieties, we commence with plants of **known character**, and we know something of the antecedents of the varieties produced. This is of great importance when we seek **to improve a variety** of seed which is specially suited to the soil and the climate of any given district. This is a work which is assuming greater importance every day, and it gives an opportunity for increasing many of our crops by the growth of **very productive seed** of suitable character. An examination was recently made into the variations in the growth of oats. Two crops were grown upon similar land, under like circumstances as regards climate. In the one case good and suitable seed was used, and in the other case selection and improvement of the seed had been neglected. The results were as follows :—

	Produce per Acre.	
	Good Seed.	Very inferior Seed.
Flesh-forming matter	84½ lbs.	12 lbs.
Fat and heat-producing matter . .	943½ „	295½ „

Here was a variation materially affecting the profits of the farmer in which the choice of seed made all the difference between a **satisfactory** and an **unsatisfactory crop.**

It is also important to bear in mind that by steadily continuing to pursue a system of **selection** for many years, and by having some **settled point of character** held perseveringly in view, that character can be so impressed upon seed that there appears to be **an accumulation of energy,** which manifests itself in the reproduction of that type and character, even under conditions of great difficulty. Thus we can **intensify the hereditary powers** of a seed, and render it increasingly powerful in reproducing **its own type and character.**

It is quite possible for us to have a seed possessing **great hereditary power,** and yet from want of constitutional strength it may have **weak powers of reproduction.** To overcome this difficulty, the seed of **the strongest plants** should be selected. It is thus quite within the power of the cultivator to secure a stronger and **more vigorous growth of plant,** without in any way decreasing the heredi-

tary tendency of the seed. The vital powers of the plant are thus strengthened, and thus, whilst the vigorous growth is **independent of the hereditary character**, it gives an energy to the production of seed, and this seed of necessity possesses strong hereditary character.

The age of the seed has been observed to influence its growth and the general development of its produce. If we take the case of **swede seed**, we find that **new seed** has a vigour of growth far in advance of similar seed which may be one or two years older. It is a matter of notoriety that the growth of plants grown from new seed is always **more necky** and more disposed **to run to seed**. There is a disposition to a **greater rapidity of growth**, and often at a sacrifice of good form; and this becomes still more evident when it is encouraged by very prompt and active manures. **The older seed** makes a **slower progress**, but it is **less easily checked** in its growth. The plant now preserves its form, and the feeding quality of the bulb is also better. Generally speaking, the two-year old swede seed is in every way calculated to produce a larger quantity of high quality food than newer seed, even in those cases where the total weight per acre of the crop may appear to favour the newer seed. By reason of this steadier and firmer growth, the plants produced from two-year old seed are less liable to mildew, which almost always arises from some check in the progress of the plant, predisposing it for the development of this fungous growth.

CHAPTER L.

VERY closely associated with the conditions which regulate the production of pedigree seed we have a subject which is surrounded with considerable doubt, namely the principles regulating a "change of seed." This does not simply mean the purchase of a supply of seed from another grower, but the manner in which seed is best prepared for any district or soil by its own conditions of growth. It is very well known by cultivators of the soil that if the seed grown upon a farm be sown again and again upon that farm, on the same kind of soil, and in the same climate, it is less productive than corn of similar quality grown on some other kind of soil or in some other district. Almost every farmer recognises this truth, and is able to state the district from which he prefers to draw his seed-corn. This is the "change of seed" referred to, and it opens up an excessively important national question on which at present we are in doubt—not that any one doubts the advantage of making the change, but no one has clearly laid down the rules which should guide us in carrying out the practice.

It appears probable that, upon the greater portion of the districts in which seed-corn is usually grown, we rarely, if ever, find the conditions of growth as perfect as they might have been. The soil and climate may not, in all respects, meet the plant's re-

quirements; some imperfection therefore exists in the seed. A continuation of these unfavourable conditions—year after year—would make any such defective conditions more and more evident, and such seed would become decreasingly valuable. Let some of this seed-corn be sent to a district of a very different character,—for example, as from the sandstone soils to the limestone soils, or from the chalk to the clay,—the probabilities are that the seed would produce a better crop than if sown on the same ground as that on which it may have grown. The change of soil and climate may be the means of rectifying certain imperfections, and the seed produced acquires an increased vigour of growth and increased powers of reproduction.

Local experience does afford a certain measure of guidance, and it may be that, if such local opinions were to be recorded and systematically contrasted with the composition of the soil and the special peculiarities of climate, much valuable information would be ready for our use. In this way we should be able to lay down some sound and definite principles, and learn from the practice of the several districts examined those lessons which that practice has to teach. The information is greatly desired by all intelligent farmers, not from any idle curiosity, but because it would give valuable guidance in the management of seed-corn. It will be very generally admitted that a well-bred seed, having a good form and quality, and having also a good pedigree, will be used to a great disadvantage if it be grown upon a soil or in a

climate for which it is not a good change. If we knew with any degree of clearness the principles which should regulate the change of seed, it would simply become a matter of business arrangement to carry it into practice. The grower of seed-corn would not only **secure good character and pedigree power,** but he would also secure the important advantages of regulating his supplies **for different soils and districts,** with due regard to the conditions of soil and climate under which the seed-corn had been grown. The following facts may be given as an illustration of the differences arising between the use of seed-oats grown with change of soil and climate, and the employment of seed-oats grown for some length of time upon the same farm. The conditions of growth were in other respects fairly equal, but the former produced 46 bushels of oats, weighing 43 pounds per bushel, whilst the latter yielded 24 bushels of oats, weighing 32 pounds per bushel. The variation in value as food was as follows:—

	Produce per Acre	
	With Change of Seed	Without Change of Seed.
Flesh-forming matter . .	151½ pounds	40 pounds
Fat-and heat-producing matter	1253 ,,	490¼ ,,

The change of seed is in other words little or nothing more than a **change of soil and climate for the seed.** We find that under prudent arrange-

ments it results in an increase of general constitutional strength. The conditions of bodily health and strength are improved, and the result is shown in the general development of the crop. It is really a very parallel case to a change of air, water, and climate, in animal life, and the result is improved conditions of health. This is a matter of special importance, when our systems of cultivation carry a plant so far away from the conditions of life common to the wild and uncultivated parent from which it is descended. The more we establish those perfections of character which are of such great economic value, the more incumbent does it become that we should preserve the plant in the highest possible condition of health, so as to secure a full reward for our skill.

It is a very remarkable fact, and one worthy of more careful consideration than it has already received, that well-bred seeds in sound healthy condition are, like our thorough-bred horses, more than usually prepared to stand against and overcome conditions of difficulty, which are almost fatal to many other seeds. The recent wet and unfavourable seasons have supplied many confirmatory instances, and have given us great encouragement to look well to the character of our seed-corn. Nor must we be supposed to limit these good influences to seed-corn alone, for they are equally capable of assisting each and every kind of farm-seed. This has been a very weak point in farm-practice, but it is now being corrected. The same indifference was for

a long time shown to every description of live stock, but the improvements which have been made in this department of farm industry show how fully this has been recognised and attended to. But just as we examine into the influences we can exert over vegetable life, so do we see that we can modify and develope vegetation, to meet our requirements, to a greater extent than is the case in animal life. If so much has been accomplished in the one case, there is plenty of room still left for great improvements in farm-seeds.

This change of seed is also a favourable opportunity for introducing more or less rapid conditions of growth, by growing a seed of a valuable character in a quicker or slower climate. Take, for instance, the Swiss oats introduced of late years into Scotland; these, from being grown in the warm valleys of Switzerland, have acquired the habit of rushing quickly to maturity. Thus in Scotland two weeks can be gained in the preparation of a crop for harvest. This is a time which, in a treacherous climate, may make all the difference between a good and a bad harvesting. Nor does there appear to be any reason to suppose that such a change in the habits of growth is not equally capable of being engrafted on other corn-crops. It is equally probable that we may not only be able to quicken the growth, but also give our corn a more hardy character, without any loss of feeding power. Just as we find various breeds of cattle and sheep becoming more and more adapted to different districts,

with their various soils and climates, so also may we secure our several varieties of farm produce with a form and character more suitable for cultivation under a wider range of conditions. Much has been accomplished in the improvement of farm-seeds, and it is a branch of agricultural practice which offers many inducements for still further advance.

CHAPTER LI.

In addition to an abundance of plant-food ready for use in the soil, and a well-bred seed prepared to make use of that food, we also need conditions of climate favourable for bringing that seed to perfection. It must not be forgotten that the aim of the grower of good farm-seeds is to encourage variations in form and character perfectly distinct from those naturally belonging to the uncultivated plant. These proceedings do not destroy the natural character of the plant's growth: they simply modify them temporarily. As in the case of a recently bent bow, there is a tendency to return to the original form, so it is also in any altered form of plant-life, but the longer the controlling influence is exerted on the bow the weaker the resistance becomes. The reason is tolerably clear, for the natural conditions of the plant-life are manifestly those best adapted for the preservation of the species. In this direction the energies of the plant are turned as soon as it has to struggle with difficulties.

The various processes which have been practised have given a greater **delicacy of character** to our cultivated plants, and as soon, therefore, as the conditions of **climate become too severe** our crops are less perfectly developed. Hence we have certain well-recognised districts within which we find it advantageous to limit the cultivation of certain crops. These districts may be extended hereafter by various improvements, but, for the present, it is wise to acknowledge these limitations to our course of cropping. By bad management, and by want of a proper drainage of the land, we often cause **needless interruptions** in the profitable cultivation of the soil, and render certain lands unfit for the growth of some of our crops. In a previous chapter (page 229) we noticed **an artificial climate** which was **beneficial** for growth, but in this case we have the growth impeded by an artificial climate which exerts an **unfavourable** influence. The effort of the cultivator of the soil is very generally directed towards the improvement of the local climate, but when our management results in unfavourable conditions the error or the neglect (as the case may be) should be clearly recognised.

The fall of rain is a very influential section of those climatic conditions which exert a controlling power over a farmer's proceedings. There is a great difference in the distribution of rain, the fall being greater in the western districts than in the east. Advantage is consequently taken of this circumstance for growing a larger proportion of **grass and green**

crops in our **western** counties, whilst our principal **corn** districts are on the **eastern** side. The larger growth of grass and green crops is favourable for the breeding and rearing of cattle and sheep, and this also takes place in a larger proportion in the western districts. The fall of **rain** having an influence upon the **mechanical condition** of the soil, lands, which may correspond very closely in these respects, would be cultivated with ease (under ordinary seasons) in the east, whilst in the west they might be found more useful in grass, instead of being under the plough.

The average temperature naturally influences our selection of the crops which can be most advantageously grown. As a general rule the farmers of our different districts have arrived at accurate conclusions in this respect. They have naturally attempted from time to time to go beyond their neighbours, working as pioneers do to introduce improvements, and thereby new crops, and in some cases they have succeeded. The cultivation of **wheat and mangel** appears to be most successful in the **warmer districts** of this kingdom, and on the stronger soils—**clays and clay loams.** Where these cannot be successfully grown by reason of the coldness and moisture of the climate, oats, turnips, and swedes are then more generally relied upon. It must not be understood as being stated that these three crops are not grown under more favourable circumstances, for everyday observation shows the contrary. The district in which wheat and mangel can be grown successfully is much smaller than that in which oats,

turnips, and swedes can be produced of good quality. Barley takes nearly as wide a range as oats, for the hardy bere of the north closely equals the oats, and the finer varieties of oats nearly rival the best samples of barley. If the oats have a slight advantage in the colder districts and poorer lands, the barley has a corresponding balance in its favour upon richer soils and in warmer districts.

The lesson which we may learn from the experience of farmers in different parts of the kingdom is very distinct and definite. **Local conditions of climate limit the variety of crops** which can be successfully grown, and it is found more advantageous to cultivate crops which are suited to the district than to come in conflict with those natural laws which control the local climate. The farmer has difficulties enough, which he must contend against and endeavour to overcome, without increasing those difficulties by attempting the growth of crops unsuited to the district or the farm. He wants to glide with the stream, rather than pull against it. The **farm practice** of different districts is **not a matter of chance or personal preference,** but it represents a course of policy **dictated by local necessities.** It shows the best known means of utilising the beneficial influences which are in operation, and of avoiding natural impediments existing in that neighbourhood.

Are we then to consider the local practice of different districts perfect and beyond further improvement? Certainly not, but he who recklessly changes such a system, and, except after gaining much local

knowledge, **condemns** that which has resulted from **long experience** may be a bold man, but he is **not likely to farm successfully.** Many and many are the instances in which young men who have learnt farming in one district take land in another neighbourhood where the conditions are totally different; they forthwith **condemn the farmers as behind the times,** and as doing almost everything in a wrong manner. The result is tolerably certain, for **the man who will not respect local custom cannot be a successful farmer.** But whilst experience proves the value of local custom, it encourages **prudent advance.** It is as if we had to feel our way in the dark, and for a time it must be so; but when science has thrown light upon the work of the past, and when we know and understand the difficulties of the present, we shall probably see a clearer, a more direct, and a more successful course for making improvements in our practice.

There is another view of the difficulties thus arising from these variations in soil and climate, which is of a more satisfactory character. It renders farm practice an occupation in which the work **need never be one dull routine of labour,** but each and every modification leads to the inquiry of the why and the wherefore. The bountiful provisions of nature have given us abundant means for securing our comfort and well-being, and for the support of animal life, but the variations caused by climate give **additional opportunities for the exercise of the mental powers** we possess. The experience of the past is

rich in its lessons of truth, and when these have been secured we shall then be better prepared for learning something more, but it is probable that as we advance we shall value more and more highly a familiar acquaintance with facts. These are said to be stubborn things, but whether that be so or not, they are certainly a safe foundation to rest upon, but the man who disregards local experience can scarcely be considered a prudent leader.

CHAPTER LII.

IN the growth of the Oat we have one of our most hardy corn crops, and it appears specially adapted for that portion of our tillage land which is situated on high lands and in severe climates. The excellence which is attained in Scotland, in the character of this corn, is generally acknowledged, and the oatmeal obtained from it is unequalled. There is a very great difference in the quantity of oats grown per acre, as well as in the quality of the grain, and it will be well to see how far the successful practice of good farmers teaches us the best system for cultivating the oat.

The author was directed by the Lords of the Committee of Council on Education to carry out an inquiry, in 1877, as to the variations existing in the oats, barley, and wheat grown in this country, and as to the causes of these variations. It was shown that the crops of oats, that year ranged from 10 to 80

bushels per acre, and the weight per bushel ranged from 20 to 49 pounds. These were differences which were self-evident to the general observer, but there were other variations which did not reveal themselves to the eye, and these were variations of feeding quality. Every farmer of experience and every horse-keeper knew perfectly well, that there was not necessarily an equal quantity of actual food in an equal weight of oats. These opinions were looked upon as matters of prejudice, which would disappear as persons knew more of the nature and character of food. The results of the chemical examination of properly selected specimens of oats, most perfectly confirmed the accuracy of the opinions held by practical men. The available nitrogenous matter (flesh-forming matter) ranged from half a pound to 4½ pounds per bushel, and the available carbonaceous matter (fat and heat producing matter) from 13½ to 31 pounds per bushel. When the produce of food was calculated on the growth per acre, it was found that **one acre** of land had produced nearly **fifteen times** as much available carbonaceous matter, and nearly **seventy times** as much available nitrogenous matter **as another acre.**

There were many circumstances which contributed towards these variations. The general character of the cultivation was one of these. **A thoroughness in the tillage work** made a very marked difference in the result. **Feeble efforts at cultivation,** a thin slice of soil turned over, leaving a hard and impervious barrier beneath, these gave the growing

crop difficulties to encounter which rendered successful growth absolutely impossible. Other instances came under observation in which similar land, under like conditions of climate, was subjected to a thoroughly good tillage. The roots of the crop were then able to spread throughout the soil, which had been well permeated by atmospheric air, and was therefore in a healthy condition. In brief, the land had been thoroughly well cultivated in the one case, and negligently worked in the other. The cultivator was rewarded, in the one case, with 50 bushels of oats weighing 43 pounds per bushel, and the bad farm manager only gathered 10 bushels, weighing 22 pounds per bushel. The latter case was marked as one of the worst instances of bad farming, but the other (a neighbour) produced what was a thoroughly good crop for the district.

A reference has already been made (page 247) to the influence of **a good seed,** for upon a judicious preparation of seed the measure of success very greatly depends. We must **not only** have a good quality seed, but one especially **suited to the soil and district** upon which it has to be sown. The very best seed-oat that was ever produced **cannot be equally suited for all kinds of soils and climate,** any more than a thoroughly well-bred sheep can be equally suitable and valuable for use everywhere. The preparation of the seed, we have noticed, is of a twofold character—first, by careful selection and cultivation, they secure the variety of oat desired, and then they intensify by repeated growth

its several points of character; secondly, they prepare that seed by a proper change of soil and climate for use on any special farm, or for any particular district.

Oats, barley, and wheat are all known to us as cereal grasses—**corn-producing grasses.** In carrying out the cultivation of the oat crop, we more especially find evidence of a **conflict** existing under this name. Grasses are a group of plants which are cultivated **for their leaves,** but we have, in the case of these corn crops, grasses grown for another purpose. To secure the successful growth of corn, we are compelled to encourage **for a time** the grassy growth of the young plant. We could not secure a fair proportion of root, if we did not thus encourage the growth of the leaf; but when this result has been secured, we then do our best to **turn the energies of the plant** into a very different direction. The farmer has therefore to secure a sufficient growth of leaf to be sure of a good yield of corn, and then he needs all the powers of the plant to be devoted **to the production of seed.** It is very frequently difficult to regulate the energies of the plant just as we desire.

A moist climate and a highly fertile condition of soil have a tendency to make **the grassy growth** continue for **too long** a period, and the quality of the **corn is greatly injured** thereby. A series of four crops of oats which the author examined may be referred to here. They were grown upon similar soils and under somewhat similar management, but in very different climates.

Specimen.		Miles from the sea.	Feet above the sea.
A	was grown on a small island . .	2	200
B	„ „ a highland farm . .	60	1100
C	„ „ an inland farm . .	16	300
D	„ „ an inland farm . .	30	800

The produce of oats per acre obtained in each of these cases was as follows :—

				Lbs.
A.	44 bushels of oats, weighing	29	pounds per bushel	=1276
B.	32 „ „ „	40	„ „	=1280
C.	42 „ „ „	36½	„ „	=1533
D.	48 „ „ „	38	„ „	=1824

We see in this series of crops that as the distance from the sea increased so the weight per bushel increased, the heavier and firmer growth, being greatly due to the condition of the climate, which was less favourable to the prolonged grassy growth of the crop. We must not misread these observations, and say that proximity to the sea **always** decreases the weight of corn per bushel, for that would be a distinct error. In fact the largest crop of oats grown in 1877, namely, 80 bushels per acre, weighing 40 pounds per bushel, was grown near the sea. The rule which practice teaches is, that those conditions either of soil or climate which unduly favour **a long continued grassy growth,** give a **light** and poorly developed **corn.** But the conditions which produce such inferior corn give a very **superior straw.** If we could so control the crop that the nutritious matter in the stem should, in the ripening of the crop, be driven up into the grains of corn, we should

enrich the grain at the cost of the straw. When the grassy growth predominates, the straw retains valuable nutriment which might have been utilised and concentrated in the grain.

Thus we have very great differences **in the quality of oat straw** which are often overlooked, because some persons have not contrasted their own growth with that of others. In one district, therefore, we find oat straw valued as a good food; and in others they express surprise at the fact of its being so used. Both are very nearly right in their opinions of their own produce, but an examination of the chemical composition proves to us why these oat straws differ so much in feeding power. To expect **uniformity of opinions** amongst farmers would indicate that the **circumstance and conditions** under which they act, and the results arising therefrom, are **uniform** also. If these local experiences be accurate there must be **variations in the results**, corresponding very closely with the **variations observable in the general conditions of growth.**

CHAPTER LIII.

None of our corn crops equal **the Oat** for making a good growth **in strong turf,** such, for instance, as is produced by ploughing up land which has long remained in grass. The **wheat** naturally luxuriates **in a turf of younger date**; but for a tough furrow

slice such as that referred to nothing equals the oat. This may be traced to the penetrating power of the roots of the oat crop, for they not only search into and amongst it for plant-food, but they encourage a rapid decay, and thereby facilitate subsequent tillage operations. It is for this reason that the oat crop is so generally chosen for this duty.

Few crops so frequently give proof of the disadvantages arising from **the want of proper drainage** as the oat. This does not arise from other corn being less influenced by this bad condition of the soil, but it may be traced to the fact that **the oat can struggle against greater difficulties** than other corn, and it is frequently chosen for the work. Every observant farmer knows that on these wet soils the produce is generally less, and that it is of inferior feeding quality. We are able to confirm the truth of this opinion, by an accurate examination of two crops grown upon land having the same character and in the same climate, differing only in the drainage of the soil. It may be taken as a fairly representative case under average conditions. The land which had been drained yielded 38 bushels of oats per acre, weighing 42½ pounds, whilst the undrained land gave only 26 bushels, weighing 37 pounds per bushel. In the former case 1075½ pounds of useful feeding matter was produced, and in the latter instance, 637½ pounds.

The **ripening of the oats** is also influenced by the **dryness of the soil,** and by the moisture of the atmosphere. It is very commonly supposed

that the ripening of corn has been completed when it is carried to the stack in good condition; but farmers and their ploughmen know better than this. New oats are looked upon with suspicion, and their use delayed, as long as old oats are within command on the farm. When the corn has been in the stack for four or five months, and especially when **frost** has passed through the stack by the cold piercing wind penetrating it, the farmer knows that he may then use the oats with safety. The change which takes place during this time has yet to be determined by analysts. It is, however, more than probable that much of the nitrogenous (flesh-forming) matter existing in the oat when harvested, remains in **an imperfectly matured condition.** What the farmer understands by this **ripening in the stack**, is probably the change of this nitrogenous matter into the more perfect form of gluten or some corresponding **albuminoid.** Some may be disposed to enquire, how it is that farmers and their ploughmen can know anything about such a point of character? The old saying applies here as in another case,—"The proof of the pudding is in the eating," and here also the use of the oat as food gives the necessary proof. The ploughman finds the use of new oats causes an irritation on the skin of the horse, which soon leads to mischief and disease. The horse, instead of deriving that nourishment from the new oat which shall enable him to do his work, finds the food give more inconvenience than support, and he *rapidly* loses condition in struggling to accomplish

his daily task. In the meantime, the imperfectly ripened nutriment has to be separated and removed from the blood, so that it is not merely in a large degree useless, but it is distinctly injurious.

The more usual mode of ripening the oat is by the influence of cold, and the farmer then recognises the oat as being **in good condition,** but this would not take place in very large stacks of corn. The thickness of these stacks effectually prevents the air penetrating to any great depth; but even here the oat ripens, but from a different cause. That which cold accomplished, **warmth also effects.** The larger size of these stacks causes a moderate warmth to be produced, which spreads through the stack, gently and slowly accomplishing the necessary changes. We find a somewhat corresponding ripening taking place in other kinds of vegetation, which will be referred to subsequently. The details of these changes have yet to be determined by chemical analyses; but the farmer knows when these changes have taken place, and that they are necessary, and the light of science will in due course give us the fuller information we need.

In the successful use of **the Swiss Oat** in Scotland we have another encouraging instance of the advantages secured by modifying the rapidity of a plant's growth, by bringing it under the influence of another climate. In this way a slower or a more rapid habit of growth may be given to the seed. In the present case, the rapid growth of oats in the Swiss valleys has become a habit of the plant, and

when sown in Scotland we see that it often comes to maturity two or three weeks sooner than other oats. This difference of time may settle the question of a good or a bad harvesting. If this result can be obtained by an almost accidental variation in character, may we not expect more influential results under a well-designed system, and with seed having higher feeding powers?

The use of seed-oats grown in Scotland has secured a well-deserved reputation throughout the larger portion of the kingdom, by reason of the larger produce and higher quality of the corn. This gives another instance of the assistance which climate renders us in the growth of seed. It must not be for a moment supposed, that it is suggested that good seed oats cannot be grown out of Scotland. Our everyday observation disproves the idea. The lesson which may perhaps be safely gathered is, that the climate of Scotland, being so favourable for perfecting the oat, might be utilised by growers, in sending seed to be grown there for a change. The continuous care taken by our best seed-growers in the selection of seed, and in increasing its pedigree character, may perhaps be usefully supplemented by its occasional growth in this most favourable climate.

It is also worthy of notice that just as the oat is grown in its greatest perfection, so does the oatmeal take a more commanding position as an article of food. There are possibly some objections to its use in hot climates, and for persons taking very little exercise; but it is justly regarded in

the northern parts of the kingdom as the best and most suitable food for sustaining the body through long periods of fatigue. This is fully accounted for by reason of the high percentage of flesh-forming matter it contains. Thus, if we compare the oatmeal with wheaten-flour, we find the former containing about 50 or 60 per cent more flesh-forming matter than the latter. In the large percentage of fatty matter found in good oatmeal (say 8 to 10 per cent) we have another point in its favour, for this renders it more perfect as a food. An examination of its composition reveals to us the why and the wherefore of that popular favour, which it so justly receives from a large proportion of the inhabitants of this kingdom. It is a crop which certainly merits every care and attention, to make its cultivation more perfect, and its produce more abundant.

CHAPTER LIV.

THE cultivation of **Wheat** is looked upon with especial interest, as it is the grain from which we obtain the flour so **generally used for making bread.** There are more varieties of wheat than of any other corn, and this arises from the great desire to use the best and most suitable seed. Seed-wheat differs greatly in form, in habits of growth, in hardihood of character; and these variations have been produced in order that the peculiarities of soil and

climate may be most fully utilised. To sow a finely developed white wheat on a cold clay soil, and in a severe climate, is simply to seek for a failure in the crop. Whereas, if a strong, coarse, red wheat is sown upon our more favoured wheat soils, we thereby often lose the opportunity of securing the highest quality produce. Very great skill has been shown by farmers in modifying the growth of wheat, so as to have it about **as fine in character, as is safe** for the neighbourhood in which it is to be grown.

To understand this influence fully it should be remembered that we have **two opposite points** of **character,** between which the cultivator has to choose how near he will approach the one or the other. We have in the one case **great hardihood of character** secured, and such seed will stand much rough weather, yielding a produce having a rather coarse texture and a large yield per acre. The corn when ground would yield strong bran and somewhat inferior flour. On the other hand, we have **very fine and delicate wheats** which will produce a plant which will die if exposed to severe cold in the winter, and which also needs much warmth in the summer to bring it to perfection. The grain of such wheat is distinguished by producing but little bran, and that of a fine texture, together with an abundance of the best flour; and it is capable of yielding a large produce per acre. In the former case we have those conditions which enable the wheat plant to struggle with the hard and adverse conditions of life; and in the latter

instance we have the offspring which has been nursed under the most favoured circumstances which can be desired.

Between these two extremes of character we may range our **immense variety of seed-wheat.** The skill of the farmer is constantly exerted to secure as high quality produce, as the character of his soil and the probable severity of his climate will safely permit. If he imprudently attempts to secure **too high a quality,** he is punished by more or less **failure** of the crop. **If he is too cautious,** then he produces a more **inferior quality** of corn than he need have done. He has a choice which is attended with much risk, for he desires to secure as good quality corn as his soil, and the uncertain weather of the coming season, will permit. He, very naturally, is guided by the general character of previous seasons in that particular neighbourhood; but if the season is exceptionally unfavourable, he suffers because he has attempted to secure too high a quality. A farmer is very much in the position of a sailor, who before commencing his voyage has to set his sails, but who has no power to alter them afterwards. Will he set them for speed or for safety? Will a rapid voyage or a safe voyage be chosen? Some persons smile at farmers complaining so much about the weather, but they smile because they are ignorant of the risk farmers have to run. They can sympathise with the sailor, even when he has the opportunity of trimming his sails, but how much more so if he could not alter his sails. The farmer

has to select his seed-wheat, either for a more, or for a less remunerative crop, but, having made his choice, he is bound to accept the issue.

During the adverse seasons of the last four years he has had again and again to regret that he endeavoured to grow wheat of too good quality. If he could have anticipated such unfavourable weather he would have sown a hardier and stronger seed, and sacrificed some of the high quality he hoped to gain. As the result has been, he generally failed to secure that high quality; but he would have had a larger yield and a better quality, if he had aimed at a lower but a safer course. **The farmer has to make his choice under unknown conditions,** because the season which will determine whether his efforts shall be crowned with success, or blighted by disappointment, is beyond his knowledge. It is not simply in reference to wheat that the farmer has to decide, before he knows the conditions he has to provide against. No other commercial industry is similarly situated, and the exceptional position which agriculture consequently occupies demands fuller recognition. Even in 1877, one of the worst years for wheat in the unfortunate series we have had, some encouraging instances were observable of the power of well-bred seeds to overcome the difficulties of a bad season. Two cases may be instanced which came under the author's examination in the official enquiry already referred to, showing the results obtained from a good seed and one which was still more powerful. In the case of the most suitable

seed 60 bushels of wheat per acre, weighing 63 pounds per bushel, were obtained; and in the case of the other 40 bushels per acre, weighing 64 pounds per bushel, were obtained. Surely we have encouragement here to carry forward our efforts for producing **hardy seed of good quality.**

The several varieties of **seed-wheat** must be recognised as subject to modification; there is **no permanency of character.** We are in each and all these cases dealing with seed which has been **artificially brought to its present form,** and which **will return** to its natural character, unless by selection and cultivative processes we kept it up to the required standard. The time cannot be long delayed when the importance of **hereditary character** in farm-seeds will receive more encouragement from our national societies. Much good has been rendered to the character of **Live Stock**; and we have arrived at a degree of perfection which enables us to combine **hardy character with the highest quality of meat.** What would have been the value to farmers if our **seed-wheat** had been so improved that we could have secured in it the same happy combination, namely—**hardy character and high quality.** Nor must it be thought that this necessity is limited to wheat: **every other farm-seed** awaits similar improvement; and until this has been secured throughout the series, agricultural produce will not attain that excellence of which it is capable.

Closely associated with the selection of the seed-

wheat is **the mechanical condition of the soil** at the time of sowing. By almost universal testimony wheat requires **a firm seed-bed**—not hard nor tough, but firm and steady. It must be in such a condition that the roots can establish a firm hold upon the soil, and yet penetrate it with freedom. The presence of a moderate supply of organic matter—such as we secure in a good clover ley—contributes towards this result; and for this reason, if there were no others, the successful growth of clover becomes such an excellent preparation for wheat, combining **firmness, with freedom** for the extension of the root. On many of our clays there is a very marked difference observable as to the best condition for sowing it with wheat. In some cases the wheat may be sown in a muddy soil, and yet it grows well; on somewhat similar soils the seed would be unable to grow with any degree of freedom. The presence of a small quantity of sand or organic matter will generally account for the differing results. The firmness of root is in some soils especially necessary to avoid the wheat being **thrown out by the frost**, and thereby being destroyed. The cases are very rare where this may not be decreased, if not entirely prevented, by introducing **more organic matter** into the soil—not in the form of farm-yard manure, but—by encouraging the growth of clover, and thereby improving the mechanical condition of the soil.

CHAPTER LV.

OF the several changes which we had introduced into **seed-wheat,** that which determines **its time of sowing** must not be disregarded. Thus we have some wheat which must be sown in the **autumn** of the year, whilst others must be sown in the **spring.** To reverse the time of sowing would in all probability lead to one crop never ripening, and the other would be killed by the winter's frost. There is **nothing permanent** in these points of character, and by cautious management they **may be changed** from the one into the other. Still we must ever remember that although we cannot permanently alter any point of character, we must **not suddenly** disregard the work which has already been accomplished.

It is by no means uncommon for the **seed** of wheat to be so far **over-developed** that it cannot be relied upon for seed. It may have been rendered the perfection of wheat for grinding purposes, but **overdone for seed.** An instance of this kind came under the author's observation. A remarkably **fine white wheat** was sown on a good red-sandstone soil, in one of the midland counties, and as the land was in thoroughly good condition an abundant yield of excellent wheat was anticipated. The winter was not of an exceptionally severe character in any way, but the plant was excessively **feeble and**

delicate, still hope was not given up. The quantity of seed was not sufficient for the entire field, and the headlands around the field were sown with the tail-wheat of the same sample. This portion of the field presented a much more promising appearance during its growth. At the time of harvest this so-called inferior seed yielded a splendid crop of high quality wheat, but the finest seed resulted in a failure. The lesson we may learn from this is, that improvements must be limited by the constitutional strength of the seed, and that even a good practice may be carried to an excess.

The ripeness of the wheat at the time of the corn being cut materially affects the quality of the corn. If the wheat becomes thoroughly ripe before the cutting takes place, there is not only a liability to loss from some of the corn being shaken off, but the quality is somewhat injured. If it be cut whilst there is a slight greenish colour remaining, the skin of the wheat ceases to thicken; the bran is therefore finer and the proportion of flour is increased in quantity. Even this improvement must be practised with moderation and caution; but it is by far too frequently seen that wheat is allowed to become over-ripe before it is cut. For use as seed-wheat it is well to allow the ripening to take place naturally; but for the miller's use it may be cautiously anticipated. The changes which take place, in those latter stages of ripening which precede the harvesting, are calculated to thicken the skin of the wheat; and although the

additional quantity of bran is objectionable from a miller's point of view, it becomes a valuable protection for the wheat which has to be used as seed.

Much has been said respecting **the continuous growth of wheat,** and it is certainly a question of great interest. It is by no means a recent modification of farm management, but one which, for 150 years, has been under more or less successful practice. We find it attempted by **Jethro Tull,** who imagined that as vine culture was carried out on the Continent, on lands permanently devoted to its growth, so by adopting a similar system for wheat he hoped to accomplish the same end. His efforts were not successful, for **his tillage** was very **imperfect,** and **he undervalued** the assistance of **manure.** Subsequently we had **the Lois-Weedon system,** which possessed many advantages over its predecessor, and for several years in succession produced thirty-four bushels of wheat per acre. The system was really an alternate fallow and wheat; but instead of having all the land in fallow one year, and having all in wheat the following, Smith adopted the plan of having **half** of the land **in fallow,** and **half** of it **in wheat** year after year. In fact the land was sown so that 2½ feet was growing wheat, leaving 2½ feet free for fallowing; then another 2½ feet of wheat, and another 2½ feet for fallowing. His plan was distinctly in advance of Jethro Tull's, and he promoted his success by **deeper and more perfect tillage and by a use of manure.**

The series of experiments carried out by **Messrs.**

Lawes and Gilbert are the **most perfect** we have, and the average produce has been about 36 bushels. It remained, however, for **Mr. Prout, of Sawbridgeworth,** to give **the best practical test** of **the system.** He has carried out the system on a farm of 450 acres, not so much to test the merits of the question, but simply for business purposes, and only so far as from time to time it might appear to be the most profitable system. In this case the entire produce of the land—corn and straw and hay—is sold and removed from the farm. **He cultivates the land very thoroughly by steam machinery,** and he expends about 50 shillings per acre annually for **well-selected artificial manures.** The soil is a **clay-loam** resting on drift-clay and gravel, and is **thoroughly well drained.** In 1877, which will be remembered as one of the recent series of bad harvests, the author visited this farm and took specimens of wheat for analysis. The crop selected yielded 48 bushels of wheat per acre, weighing 62 pounds per bushel; and this was **the fourth crop of wheat** in direct succession, and **the ninth corn crop** without any intervening crop or bare fallow. This is a system of farming which not only **needs thoroughly good cultivation and well-selected manures,** but it also requires **a strong loam or clay soil containing a good reserve of dormant matter** to be brought into work. It must also be assisted by the use of **strong and hardy well-bred seed,** ready to work with energy in the face of any difficulties which may arise.

The complete ripening of wheat is an important and necessary **sequel, to** the early stage of ripening which precedes the **placing in stack.** What are the chemical changes which take place in this final stage of ripening, has not been fully determined. Farmers and millers are both aware of the necessity which demands it; and although some small proportion of our wheats are ground before this ripening is completed, yet the injurious effects have to be checked by grinding in with them some old wheat, or some suitable foreign wheat.

The character of the **wheat-straw** produced, also demands the farmer's watchful care. As we find variations in the form and character of seed, so do we find variations in the straw. These differences arise from a series of causes. **The seed-wheat** used, primarily influences the character of the straw: it may predispose it to be a long straw, a short straw, a weak or a strong straw, a white or a red (tinted) straw. **The climate** also exerts its influence, for it may encourage or check the progress. **The soil** also may prevent a straw predisposed to be strong, really becoming so, by reason of some necessary material being absent. On the other hand, the soil may give unusual strength to a naturally weak straw. Reference has already been made (page 258) to the compound character of these cereal grasses; and in wheat we have all the conditions ready for being developed into **a grassy growth,** instead of allowing the corn-producing tendencies to retain the supreme influences.

The quality of **wheat-straw differs with** the degree of ripeness at the time of cutting, for any nourishment remaining in the straw, instead of being drawn into the grain, necessarily adds to the feeding value of the straw. Hence we find, as a very general rule, that those conditions of **climate which favour the corn-producing powers** of the wheat crop, **yield the poorest feeding-straw.** On the other hand, if the climate favours the **grassy character** of the plant, and only feebly assists the production of the grain, then we find wheat-straw which is often quite as **good for feeding purposes** as any oat-straw.

CHAPTER LVI.

There are three distinct objects in view in the growth of **Barley** which claim a passing notice. The first object is the production of barley of high **feeding quality.** Here, as in the case of wheat, a well-cultivated and fertile soil, and a moderately warm climate, utilised by a well-bred seed, will secure a barley of this character. In those crops which follow a good crop of **Swedes liberally fed upon the land,** we generally secure our barley of the highest feeding power. The danger we have to fear in such cases is an excess of rain, which may predispose the crop to run into a strong growth of straw. When this danger is anticipated, an application of

from two to four cwts. of common salt per acre, sown as soon as the seed-barley has been harrowed in, is usually found to prevent the mischief. This result is due to the steady check which the salt gives to vegetation, inducing a slower, steadier, and firmer growth, and rather tending to throw the crop into a more perfect seed-bearing condition.

The second object aimed at is the production of a **good malting barley.** This has generally proved to be one of the most remunerative descriptions of barley produced, provided it could be grown of very superior character. The right and proper seed is, of course, one of the most important conditions to be secured, but to this we shall refer again. The several conditions which applied, as making a barley exceptionally **good for feeding purposes,** are in some degree **objectionable for malting.** The abundance of **flesh-forming matter** which makes barley so good for food, is objectionable in a malting barley. We have, therefore, to avoid the conditions which favour a large production of this flesh-forming matter, if we would avoid that result. It is a matter of common observation that when barley is sown after a crop of roots has been fed on the land, the malting character is distinctly injured. Hence it has become a very frequent practice to have **a crop of spring wheat** instead of the barley, and sow **the barley after the wheat crop.** The result is almost invariably, a better quality of malting barley.

But some would object to this, on the plea that **two white straw crops** should never be grown in

direct succession. For a long time this was supposed to be the teaching of agricultural chemistry, and under the authority of its supposed prohibitions, it became one of the most common conditions inserted in the leases of land. So long as the land was feebly cultivated and still more imperfectly manured, so long it was possible to grow a good sample of malting barley immediately after a crop of roots, where now it is absolutely necessary to have some crop to take off the rankness of the manure. The author had somewhat recently the opportunity of receiving the assistance of two of the best brewers in Burton-on-Trent, and the history of some of the best malting samples of the year were traced out. The finest sample of malting barley grown that year,—portion of a crop of 39 bushels per acre, and weighing 57 pounds per bushel, —was a second crop of barley after a crop of wheat. Thus the reducing influence of two crops of corn left the land in highly productive condition, as was indeed shown by the crop, and yet in that temperate condition that it could produce the most delicate growth.

The condition in which the nitrogenous matter may be present, is even more important than the percentage. If any of it is imperfectly matured, it has a tendency to cause a troublesome fermentation subsequently, whereas, if the ripening has been perfected, the fermentation is likely to be gentle, and held under proper control. It is for this reason that malting barley is allowed to become so

thoroughly ripe before it is cut, even though it involves loss in harvesting in consequence. It is a remarkable instance of the extreme **accuracy of the judgment of some maltsters,** that they are able to detect such imperfect maturity **by the eye** with the greatest nicety. In the official inquiry already referred to this was severely tested, and barleys which had been classified according to their respective conditions, were **proved upon analysis to correspond most accurately with their supposed composition.** It is just the same with **the skill** acquired by millers, **in determining the history and character of samples of wheat** placed before them. In both of these cases **farmers very closely approach** to a similar knowledge, and these facts should be more generally recognised, because they help to show **the advanced knowledge** which has been already **secured by farmers, even without the aid of science.** Facts like these also show how rich is the store of accumulated information which farmers possess, and from which we shall deduce a clearer and more complete knowledge of the Principles of Agriculture.

The process of malting is carried out, for the purpose of preparing for the **starch** being completely changed **into sugar,** as a stage preliminary to its fermentation. In doing so, we make use of the natural powers of **germination** in the barley, to enable us to imitate, on the floor of the malt-house, that which takes place in the soil. As soon as the germ of the barley commences to make growth, a body of a very

peculiar character is **formed around the germ**, and this body is known as **diastase.** The germ of the barley cannot make growth without proper **food** to make use of for that purpose, and these materials **must be supplied dissolved in water. The food** for the germ to use **is stored up** in the seed in a condition prepared **for being kept** a long time, if necessary, and **not in a condition ready for use.** As soon, therefore, as germination—or the growth of the germ—takes place, the store of food has to be prepared for the young germ, and the agent which prepares it for use is this diastase. Thus **the agent** which is able to turn the insoluble starch of the seed into soluble sugar, is **produced at the moment it is required,** by one of the earliest decompositions resulting from germination.

The diastase is formed from some portion of the **nitrogenous** matter present, and another portion **yields ferment** in the process of brewing. It is this latter portion which sometimes induces a riotous and uncontrollable fermentation. If the nitrogenous matter be of a **fully matured character,** and it exists in the proportion of **1 to 10 of starch,** it then appears to be **sufficient and satisfactory** in its influence. **An excess,** especially if any of it be in an unhealthy condition, is very objectionable, and **a deficiency** makes the sample work in an unsatisfactory manner. Yet even these nice distinctions are determined by the system of management pursued, and the course of practice is advisedly arranged so as to accomplish a predetermined object.

The character of **the seed-bed** exerts a powerful influence on the growth of a crop, and in this respect **barley is unusually sensitive.** In one case which the author examined, the seed was sown on one portion of the field in excellent condition, but a heavy fall of rain threw the rest of the field into heavy working. On the latter portion the growth was never satisfactory, and the produce was 24 bushels per acre, weighing 54 pounds per bushel. On that portion of the land which was sown in good condition, 40 bushels of barley per acre was obtained weighing 58½ pounds per bushel. The difference in the amount of actual food produced per acre in the two cases was 1863 pounds where the barley was sown in a good condition, and 1064½ where it was sown after a shower of rain. No doubt it would have been more prudent to have stopped the sowing, so as to have allowed the soil to get into a good condition again, before sowing the remainder of the field. It also shows how greatly **the farmer's success is influenced by circumstances, which are apparently of little moment** in the judgment of the superficial observer. The same cost for rent, taxes, labour, and seed, was incurred in both cases, the result was a source of profit in the one case, and a cause of loss in the other.

CHAPTER LVII.

ANOTHER object which is sometimes sought to be attained in the cultivation of barley is the growth of seed-barley, which shall be specially adapted for producing a very good malting barley. It is well known that some of our best malting barley has been imported from France, and in the attainment of this result much care has been taken in the proper preparation of the seed. No one has done more good service in this respect, than the late George Gibson Richardson of London, a name which will be long remembered in connection with the improvement of malting barley. The over-development of corn has already been briefly noticed (page 271), but in the case of barley this has long been more fully recognised and guarded against. For malting purposes we require the barley developed to an excess, which is inconsistent with its producing a strong and healthy plant, capable of yielding a crop of corn. For the maltster's purpose we seek to obtain a barley possessing a very thin and delicate skin, a small proportion of nitrogenous matter, an excessive quantity of starch, conditions which frequently prevent such barley being hardy enough for seed. In some cases it is true good malting barley being used for seed manages to glide through its duties satisfactorily, but, as a rule, the safer course is to take some of the tail-barley

from a superior sample, and use that for seed. This tail-barley consists of less fully developed grains, and for this reason, less unfitted for use as seed.

Another plan is adopted, which has special merits. A sample of such tail-barley as has just been described, sown upon a strong soil in a favourable climate, will produce a barley which has lost all trace of malting character; but what is the real change which has been accomplished? The hereditary habit and character of the barley has not been altered or reduced, but we have lost sight of all evidence that it ever possessed, or that it still possesses, any special tendency for producing good malting barley. It looks like an ordinary sample of feeding barley, and, placed side by side with such a barley, little or no difference would be observable. Let the two samples, however, be sown under circumstances favourable for the growth of a malting barley, and their different powers become strikingly revealed. The produce of one will be little in advance of its own appearance, but the produce of the other will be a very superior malting barley, and more than usually prolific. It is this latter condition which was sought to be secured by sowing the seed upon strong land, and by giving it greater constitutional strength thereby. The character was hidden for a time, still it was not lost, but, on the other hand, the seed was being so far strengthened by the treatment, that it gained an increased power for producing an abun-

dant crop. This is a very important consideration in the value of any seed, and it is especially so in the case of high quality malting barley.

However great the efforts made in reference to the preparation of the seed, it is still impossible to produce malting barley on every soil and in every climate. Those soils which contain a free supply of lime, and are situated in a fine climate, will alone produce the finest flavoured and best quality malting barley. On other soils the grower may strive to attain equal excellence, but his difficulties are distinctly greater.

Attention has been drawn to the fact of the nitrogenous matter being discouraged in malting barley, but at the same time the formation of starch is encouraged. The reason for this is tolerably evident, for the percentage of starch determines the proportion of sugar; and this, again, regulates the quantity of spirit. Hence the larger the quantity of starch in the barley, the larger will be the quantity of spirit which can be made during fermentation. The success arising from the use of the barley therefore depends very essentially upon there being an abundant supply of starch in the grain. The process of malting produces the active agent—diastase—already referred to, but its usefulness is entirely dependent upon the greater or less abundance of the starch on which its powers have to be exerted. Before the repeal of the Malt Tax (1880) it was very important that the barley used should be of high quality and complete in itself;

therefore superior malting barley commanded a specially high price; but now that the necessity for having the diastase and starch **in one and the same seed** has ceased, that special value will probably decrease.

The advantage which the farmer will gain by this change respecting the duty which used to be charged for malting barley, will probably arise from his power **to produce diastase from barley of inferior quality,** and then employing this "active agent" upon a supply of **starch produced by some other plant.** If the cheapest supply of the materials necessary for the production of food be the primary object, the feeder will naturally secure his supply of diastase from one cheap source, and—it may be—his supply of starch from another. **Some of the inferior malting barley has great powers for producing diastase,** which bears some proportion to the percentage of nitrogenous matters they contain. This is a subject which well deserves very careful scientific examination, and **it has a most important practical bearing,** influencing, as it does, **the economic use of malt**—or rather its active principle, diastase—as an assistant **in the production of meat.**

The system of **the continuous growth** of corn has been extended to the growth of **barley** on this plan, and the facts already mentioned (page 278), showing the influence of growing barley, after barley, after wheat, necessarily lead us to the subject. This is a practice which has resulted in the production of barley of the very highest quality for malting purposes,

as already shown. It is now necessary to see how far it influences the produce per acre. The author had the opportunity of testing this on Mr. Prout's farm in 1877, and through his kindness the following facts are recorded. The crop which was examined was **the third barley crop** after two crops of wheat, and was consequently **the fifth corn crop in direct succession.** In the **bad corn season** of that year the crop yielded fifty bushels per acre, weighing $54\frac{1}{2}$ pounds per bushel, and **it was very nearly the heaviest crop of barley grown in the kingdom.** The analysis showed that it possessed full average feeding powers, for whilst the largest crop of the year contained $2256\frac{3}{4}$ pounds of actual food, this crop contained 2191 pounds. It is quite impossible to pursue this question of the continuous growth into its full details here, but sufficient has been said to show that it demands more courteous and more careful consideration, than it has hitherto received.

The influence of **bad harvest weather** is known to every farmer to reduce the feeding value of barley, and the injury to its malting character is still greater. The examination of two portions of one crop of barley—one of which was harvested well, and the other was exposed to bad weather—gave the opportunity for a careful examination. The chemical analyses gave the following results:—

COMPOSITION OF BARLEY.

	Good Harvest Weather.	Bad Harvest Weather.
True albuminoid matters (gluten) .	6·40	8·30
Starch, gum, etc.	73·97	67·35
Fatty matter	1·10	1·24
Cellulose	2·11	4·66
Nitrogenous matter (not true albuminoids)	1·01	2·27
Containing nitrogen . . .	(·159)	(·36)
Ash	2·45	2·77
Water	12·96	13·41
	100·	100·

The first impression gathered from these analyses, would naturally be that the barley had improved by the exposure to the bad harvest weather, but this is another instance which should caution us against **an improper use of chemical analysis.** The crop harvested well gave forty bushels of barley, weighing 56 pounds per bushel; the damaged crop also yielded forty bushels per acre, but this barley only weighed 40 pounds per bushel. Thus the one crop gave 1824½ pounds of actual food, and the other 1230 pounds, showing **a loss of actual food** of 594½ pounds on each acre damaged by bad harvest weather. This gives us another example, showing how greatly **the farmer's operations are liable to disappointment and loss,** by circumstances which are very often entirely beyond his control.

CHAPTER LVIII.

THE cultivation of the Mangel wurzel has been brought to a very high success in certain parts of the kingdom. Having been obtained by the improvement of the Sea Beet (*Beta maritima*), it preserves some of its original peculiarities, even under a cultivation which has materially modified its form. The wild sea beet is common on many of our sea-coasts, having a small bushy growth, with bright shining and rather fleshy leaves, and it consequently offers a striking contrast to those magnificent specimens of mangel wurzels with which we are all familiar. The object for which the mangel wurzel is chiefly cultivated is the production of a large quantity of food for stock, which can be removed from the land in the autumn of the year and kept in store for use in the spring. On many of our clays and clay loams the mangel wurzel is successfully grown; and the land still receives a considerable amount of tillage work as a preparation for the following crop. It flourishes on rather stronger soils even than the swede turnip; but whatever soils may be chosen, it is necessary that they should allow of active tillage between the drills. Two objects are thus secured—the land is cleaned from weeds, and the soil is exposed to the action of atmospheric agencies. It was at one time thought desirable to give more room between the plants in the rows than is now allowed,

but this encouraged a larger growth than is desirable.

The prizes which have been awarded by our Agricultural Societies have encouraged **an overgrowth,** which has been attained at **a sacrifice of feeding quality.** So long as the test is the weight of a single root, or the weight of **the produce per acre,** and no attention is paid to the feeding quality of the crop, such test **is delusive.** It is proved to be delusive by those who have compared their respective value for feeding purposes; and a higher price per ton is given for the smaller roots. The true test of success is the production of the largest weight of **the best food,** and not simply the greatest total weight quite regardless of quality. One simple **test** which, as a first step, would check much of this error, would be **to disqualify all mangel wurzels which float in water.** No doubt even experienced farmers have at times been led away by the attractions of excessive weight, but it has only been for a short time.

The author and Mr. Sydney S. Buckman reported in the *Agricultural Gazette* of November 18, 1878, the results of a series of experiments on the growth of mangel wurzel, some particulars of which are here given. We determined not only to take the total weight per acre, but the relative and comparative weight of the mangel wurzel. It is a very common practice for persons to take a mangel or swede in hand, and thus judge of its **solidity and firmness**; but this is very accurately accomplished by **weigh-**

ing in water—in fact, determining what is known as the specific gravity of the root. It was a matter of surprise to our friends to see mangel wurzels, swedes, and turnips, of 4, 5, 6, or 7 pounds weight each, weighing only 1 or 2 ounces in the water, and in some cases actually floating on the water, because they were lighter than the water. In the following Table these mangels are arranged in order of density, commencing with the most solid, and also the most nutritious; for recent examinations go far to justify the addition of this relative feeding character. In a parallel column the total weights of the roots grown per acre are also given.

GROWTH OF MANGEL WURZEL.

Manure Used.	Specific Gravity.	Weight per Acre. T. C.
Reduced Superphosphate and Bone Meal	1·053	33 7
Reduced Superphosphate . . .	1·028	32 14
Bone Meal	1·023	32 14
Reduced Superphosphate and Superphosphate	1·022	32 10
Blood and Sulphate of Ammonia . .	1·018	36 7
Superphosphate and Sulphate of Ammonia	1·017	34 3½
Blood and Reduced Superphosphate .	1·016	35 10
Bone and Sulphate of Ammonia . .	1·014	37 0
Blood	1·014	38 0
No Manure	1·013	27 0
Superphosphate	1·012	31 7
Nitrate of Soda and Superphosphate .	1·011	38 10
Nitrate of Soda and Bone	1·010	34 4
Nitrate of Soda and Sulphate of Ammonia	1·009	38 13½
Sulphate of Ammonia	1·008	34 3½
Nitrate of Soda	1·007	36 17½
Nitrate of Soda and Blood . . .	1·004	39 10
Nitrate of Soda (double quantity) . .	·995	43 0

Some few lessons may be gathered from these experimental growths. First, that by the use of properly selected **manures** we can **make the mangel wurzels** grown upon the same land, and from the same seed, **more or less dense and nutritious** at will. Where no manure was employed the roots were moderately dense; but **Phosphates,** especially when in a **slowly available** condition, made them **more dense**; whilst **very soluble** Phosphates and Sulphate of Ammonia and Nitrate of Soda had a general tendency **in this case** to produce **a lighter description of root.** Secondly, we observe that the heaviest crops generally resulted from the use of the most stimulating nitrogenous manures; whilst the crops obtained by the use of Phosphates were of best quality. Thirdly, it must be remembered that **under other conditions** of soil and climate these results **may be modified** in a greater or less degree. The yield of twenty-seven tons per acre, without any manure being added, shows that the land was in good condition; hence the Nitrate of Soda was used as a whip with considerable effect, producing forty-three tons, or an increase of sixteen tons per acre. If that land had not been in such good condition, the results arising from these stimulating whips would not have been as large. The manure used should be selected with due regard to the general condition of the soil; for we have before stated that "**more food and less whip**" is often desirable.

One great object in the growth of mangel wurzel

is the production of food which can be **stored and kept in good condition** until the latter part of winter, or even well on into the spring. This keeping power is therefore very desirable. The mangel wurzel, in common with all other food, **must be properly ripened** before it is used by stock. If gathered and properly **stored before they become ripe,** they may be preserved very much like good keeping apples, gathered in a similar unripe condition. Every housekeeper knows that if you attempt to store ripe apples for use in the spring, they become rotten. **Thousands and thousands of tons of mangel wurzel are wasted** every year from the same cause; and when the heap is opened many are found rotten. The primary cause is their being **too ripe when they were stored** away. A **very** warm summer might ripen a crop; but a sharp **frost ripens a mangel wurzel at once.** The whole of the root might not be ripened; but the portion touched by the frost is immediately changed in its chemical character. Hence the care which experienced farmers show in protecting these roots from the frost; but few, however, realise the full influence of this sudden ripening. Further than this, it is the **densest** and, relatively, heaviest roots, and **not the largest** mangel wurzel, which **keep best.** The general tendency of good management is in the direction of producing **a larger number of smaller roots,** and of slow and steady growth, securing these early, so that they shall be **stored in a thoroughly unripe condition.** In this way a

more nutritive food and a larger proportion of **sugar** is secured; the roots **ripen gently with the warmth of the heap.** The labours of the cultivator thus meet with their just reward, by a store of food in that condition, which combines the highest feeding quality with the best preservation, until most needed for use by the stock.

CHAPTER LIX.

SEVERAL varieties of **Turnips** are cultivated as farm crops, and these differ in character from the quick grown summer produce which is fully matured for use in the autumn, up to the hardy swede, tankard, and hybrid sorts which are needed to stand exposure to severely cold weather. The intermediate gradations are very numerous, and give an abundant choice for meeting the varied requirements of soil, climate, and the time at which they are required for use. Here, as also in the case of the mangel wurzel, there has been too great a tendency to look after rapidity of growth and **total weight** of crop, rather than the **high quality** of the produce. If it be remembered that in 100 tons of good turnips we have about 6 tons of actual food, and in 100 tons of good swedes we have about 10 or 11 tons, we shall also be aware of the fact that these small quantities of food are presented to stock in company with enormous quantities of water. So far as the animal is concerned, if

all its supplies of food come to it in this watery condition, we can readily understand that this **excessive water supply** is very injurious to its health and progress. The whole of this water has to be raised to the temperature of the body, and much of it has to be **evaporated** from the body; consequently much of the food, instead of giving warmth to the body, or adding fat, is required for dealing with the excessive quantity of water given in the food. If this food is given when it is frozen, it necessarily wastes a further portion of the food. Hence it is that when the swedes or turnips have been so grown that they have this watery character, they are almost valueless as food, and are only useful in helping stock to eat some drier food.

Excessive rapidity of growth is one of the means for producing a heavy weight of almost valueless food, and yet we require **an active growth** to secure success. In moderation this point of character is most valuable, but **in excess it is objectionable.** Much of this rapidity of growth has been encouraged, and has been looked upon as a necessity of the case, in the efforts to secure the young plant from the attack of **the turnip beetle. Two plans** have been adopted **to meet this difficulty**—namely, **a larger quantity of seed,** which may secure some plants surviving the attack, and the use of **a manure,** which makes the young plant grow **so fast,** that it has time to get its rough leaves formed before it can be eaten up by these turnip beetles. Both of these modes of defence appear weak

and faulty, and hence it is that **two other plans** have been tried—namely, **to draw the early broods away from the fields** into a convenient spot in which they can be destroyed, or to **sow** amongst the crop **something they prefer eating.** Professor Buckman[1] recommends the former plan, and it has much to commend it to favour. The latter method is very easily carried out by sowing a small quantity of mustard-seed over the field. In either case the young plant has no need to be rushed through its early stages of growth at the usual excessive rate of progress, but is allowed to make that growth under conditions favourable for its healthy development.

This rapid progress is greatly assisted by the use of **very soluble manures,** which certainly accomplish the rapid formation of the rough leaf. The race of life commenced with such rapidity is not checked when this primary object has been accomplished, but the plant continues **its hurried growth** until it has been nearly completed. The slower grown plants produced under the opposite system, appear as if they have been left far behind, and some are tempted to exclaim that they will not produce an equally good crop. Suddenly, it may be in consequence of hot weather, those of rapid growth receive **a check** and the **mildew commences** its ravages. The numberless minute fungi, of which this white dust consists, establish themselves on the crop, and forthwith draw upon the nourishment cir-

[1] *Science and Practice of Root Cultivation.* Hardwicke.

culating in the plant, like millions of small leeches upon animal bodies. The hopes of that crop depend upon a new start being made, which shall enable the plant to throw off its enemies, and continue its progress towards maturity. A fall of rain and deep hoeing of the land may also assist the crop in the effort, but it is an effort which is rarely successful. Meanwhile the **slower growing crop** has strength to resist the difficulties of the hot season, and its progress is **not checked**; consequently the **mildew does not establish itself.** The growth, so well continued, is maintained until **the cells** have been formed for receiving **the richer portions of food,** and the food has subsequently been **stored in them.** In the former case we may have **large bulbs,** but they sound empty, and **float like corks** in the water; whilst, in the latter instance, we have **bulbs of moderate size,** but they are solid and heavy, **sinking rapidly in the water.** The author recently had an opportunity of testing, comparatively, **the specific gravity** of some good swedes, with the proportion of **available flesh-forming matters** they contained. The following results were obtained:—

WEIGHT AND COMPOSITION OF SWEDES.

Group.	Specific Gravity.	Percentage of available Flesh-formers.
No. 7	1·0300	·779
,, 2	1·0296	·671
,, 1	1·0293	·671
,, 5	1·0285	·608
,, 3	1·0278	·520
,, 6	1·0250	·570
,, 4	1·0189	·494

With one exception, which admits of explanation, the specific gravity ranged with the feeding power of the swedes.

If we follow out the history of these two systems of growth, whereby we produce swedes and turnips more or less rapidly, we find that when the **quick grown roots** are exposed to a moderate **frost** they quickly **become rotten,** even if they have waited for the frost to act upon them, but the others remain firm and steady, awaiting the demands of the sheep or cattle. Finally, although as yet we have no analyses to prove the fact, **the feeding properties of the slower grown bulbs are considerably greater than the others.** We must not allow ourselves to be misled in properly recognising the influence of frost, for this differs in intensity. During very severe weather (and that of 1880-1 has been of this character) even solid and well-grown swedes have been destroyed. This is not in any

way inconsistent with the previous statement, which only indicated **greater powers for resisting** the destructive influence of **frost.** According to the severity of the winter all root crops demand proper protection.

The ripening of swedes and other slow grown turnips is often accomplished **by the action of frost,** for we find crops which cannot be safely eaten suddenly changed under its influence. It is true that some early grown turnips are, in favourable seasons, thoroughly **ripened by warmth,** but only a very small portion is matured by this agency. It is very probable that an examination of roots **ripened by the frost,** would show that under its influence **diastase is formed** throughout those portions of the plant which have been exposed to its action. The influence of this diastase would render the formation of gum and sugar a very prompt sequel, and the question of the bulb remaining solid, or becoming rotten, would probably be determined by its more or less watery character.

The small proportion of solid food contained in our best swedes and turnips shows the great importance of their **never** being relied upon as **the only food for an animal. Dry food** of some kind should always be supplied. This is **necessary** when the bulbs are thoroughly good, but if they are badly grown, the need for supplemental food becomes still greater. It is a very great disadvantage for any kind of stock to be kept upon food, which neither satisfies the appetite, nor enables the functions of the

body to be performed in a healthy manner. **The losses in** some of our **ewe flocks,** have been clearly shown to have arisen very largely **from this cause.** It is known to be the worst possible economy on any farm, for the food to be unequal to its proper duty; hence the great importance of supplemental food of a dry character being always given with swedes and turnips. Corn, oilcake, and meal may often be given with great advantage, and when judiciously employed they become a cheap means for improving the food and enriching the soil.

CHAPTER LX.

THE growth of **Clover** is gradually becoming of an increasing importance in the cultivation of the land. Under the term "**grass**" we embody a large number of very different kinds of plants, which are commonly known as "**natural grasses.**" Under the term "**clovers**" we include not only the true clovers (genus, *Trifolium*), but also a series of (leguminous) plants, differing in character in a very marked degree, and we distinguish the entire group as "**artificial grasses.**" The proper cultivation of these is daily becoming more and more important. There are difficulties which interfere with their successful cultivation, which have received careful consideration from agriculturists; and we may possibly gather from their experience some lessons of truth.

The term **clover sickness** has been given to that condition of soil which does not permit of the clover making a successful growth. For a long time this was traced to the **exhaustion of the soil** of certain substances which were needed for the crop. There is a certain measure of truth in the explanation given, but it does not meet the case fully. An examination of the Tables given (pages 102 and 120), showing the mineral ingredients removed from the soil by a crop of clover, proves how extensive is the demand thus made on the soil. **The mechanical condition** of these clover-sick soils was often an equally powerful condition, for when the roots of these "artificial grasses" were **prevented searching for food,** a deficiency arose from inability to reach the plant-food actually present in the soil.

One of the peculiarities of **clover sickness** is the **early loss of plant,** even after it has commenced its growth. This is, in many cases, due to the use of **seed grown in a warmer climate,** and thereby rendered so delicate as to be unable to withstand the more trying weather to which it is exposed. Another and still more frequent **loss of plant** may be traced to the injury done to the young plant, **by allowing sheep to be fed upon it** in the first autumn of its growth. Sheep are especially disposed to eat into the centre of the young plant and take the crown, consequently the water penetrates into the plant and it perishes. Happily the system is extending, by which the young plants have the fine weather of autumn reserved for their uninterrupted

growth. The consequence is that the **roots are extending beneath** the soil, as freely **as the plant grows above** the surface. It is true that the foliage grown in the autumn is not eaten; it falls to the ground, and some say it is so much food wasted. Experience teaches us that it is a prudent sacrifice, for any foliage so falling decays, and is reproduced in the following season; but what is of infinitely greater importance is that the plant is being strengthened for its legitimate duty, instead of being injured or destroyed. When it has this period of growth free from all interruption, we find it very much better prepared for its work in the spring, for even before any marked appearance of growth is visible above the surface, the roots are actively engaged below. The general result is, that instead of killing off a large proportion of the clover, and giving the credit of the loss to clover sickness, the plants have a way of escape given to them, and in the following season they abundantly repay the cultivator.

Much of what has been called clover sickness may be traced to **the clover** seeds being **sown with a corn crop.** In some years—warm and moist seasons especially—the young clover-seeds are encouraged to grow with too great rapidity, and **the feeble growth** rises high amongst the corn. The fact is instead of the young plants devoting all their strength to rooting themselves into the soil, their energy is mis-directed, and much growth is made amongst the corn, which of necessity weakens the clover-plant. It has not

only **failed to make a strong root** in the soil, but it has also incapacitated itself for doing so. If after this weakening process it regains some strength during the autumn, only to receive further injury from sheep grazing upon it, no one need be surprised at a loss of clover-plant before the spring. It may be difficult and expensive to avoid sowing clover-seeds in corn, but at any rate experience teaches us that an injury is sometimes inflicted on the clover-plant, and that it at least deserves careful treatment afterwards.

The application of farm-yard manure to young clover-seeds is a practice which has produced most satisfactory results, and this is only another means for preparing the clover-plant for making its future growth strong and successful. Reference has already been made to the extension of clover-root, and the important influence which is thereby exerted on the fertility of the soil. There is an advantage from this system **on almost every kind of soil,** for if it be carried out on clay-soils or clay-loams, the surface soil is mellowed in a manner nothing else can equal, and this intermixture of **rich organic matter greatly improves its fertility.** If the soils be of an opposite description—sands and sandy loams—a strong growth of clover-root entirely modifies the nature of the surface soil, and imparts to it points of character, which it never before possessed. Soils which are hungry—because they cannot keep any manure which may be added to them, and therefore need a constant renewal of supply,—these soils are altered by the growth of clover, so that the

organic matter thus added **enables these soils to keep and use manure** more advantageously. Nor must we ever overlook the enormous advantage which the clover-plant gives us for enriching such poor and hungry soils, so that **a gradual supply of plant-food** shall be forthcoming, instead of the crop having feast and fast alternating, with longer periods for the latter than for the former.

The most advantageous mode of growing clover is also shown in allowing the plant to attain a **full growth**, and then mowing it, rather than allow the crop to be eaten irregularly as it is growing. Herein lies the explanation of the conflict which so long raged, respecting the injury inflicted upon the soil by **repeated cuttings of clover.** In very many districts farmers knew perfectly well that they could **grow more wheat**—and better quality wheat—**after clover had been cut twice, than after one cutting,** or after an entire feeding of the crop. There was evidently some compensating advantage—which even now is not fully understood—and it depended upon **the growth of the clover** being allowed to be **uninterrupted.** The soil undoubtedly lost more inorganic matter by the two mowings, but by the encouragement of a vigorous growth of the clover-plant, the soil gained in exchange that which was much more valuable for such soils.

The stores of nitrogen added to the soil by the clover-root is **by no means fully recognised or appreciated,** as a means for enriching our soils with this **valuable and expensive fertiliser**

—**nitrogen.** The fact of the clover crop not being cut, until it has arrived at that period when it is most fully charged with the greatest amount of nutriment, ready for enabling the plant to produce an abundance of seed, proves how fully the energies of the plant have been engaged. The valuable crop removed from the land consequent upon the mowing, enabled a large amount of good food to be prepared for use on the farm, but the mowing stopped the formation of seed, and thereby preserved the plant in a better condition for future work. A double series of advantages are thus gained by the aid of the clover crop, and it well deserves at our hands every care. **We are very far from knowing the full value of this crop** in the fertilisation of our soils, and the time is probably not far distant, when it will no longer be said that "turnip husbandry is the farmer's sheet-anchor," but that "**the proper cultivation of the clover crop is of the highest importance for the successful tillage of the soil.**"

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